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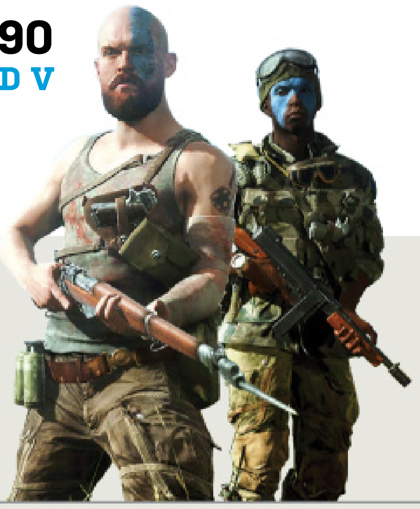

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Alan
Dexter

WORK OUT WHAT YOUR PC IS FOR BEFORE YOU PIECE IT TOGETHER

PC BUILDING is a personal endeavor. Ask each member of the *Maximum PC* team to build a system for a given task or to a certain budget, and you'd get completely different systems from each one, as personalities and experiences come into play. One may focus on storage throughput, another on processing power, graphics performance, or connectivity. That's before we even consider personal touches, such as case, lighting preferences, and so on.

Despite these variations, there are general trends, and there are two broad camps when it comes to PC building: One revels in putting the latest technologies to task, while the other is focused on how the machine is going to be used. Both methodologies have advantages and disadvantages (not least of which is cost), but for most practical cases, we advise going for the middle ground. Use the best hardware for what you need, while leaving some room for future developments.

As an aside, this is one of the reasons why it's been difficult to unreservedly recommend Nvidia's new GeForce RTX graphics cards, even though we're fans of improving the rendering quality of games. They're just a bit too close to the exciting new tech side of things, and don't do enough for how they'll currently be used. Well, that and the fact that the cards are incredibly expensive….

This issue's cover feature looks at building a mainstream gaming PC. When you build a games PC, there are lots of things you need to weigh up to produce a quality machine. It's also worth pointing out early on that even when we're talking about a "games PC," we envision that it'll be used for more than that. PC gaming is in rude health, but one of the reasons why it is, and why the PC has weathered so many console-based storms, is because PCs do other things, too. Whether you're editing photos and videos, writing your magnum opus, or simply surfing, the multi-faceted nature of the PC is what keeps us going back day after day.

Balance is key when putting this machine together. It doesn't have the fastest graphics card money can buy (indeed, an Nvidia RTX 2080 Ti costs more than this entire machine), but if you're looking for a system that will throw the latest games around at 1080p, with the effects maxed out, you've come to the right place. And it'll handle most normal things you could want from a modern PC as well—you know, just in case you get tired of gaming.

As ever with our builds, these are recommendations that we know work (we do build them, after all), but if you want to use it as the basis for something different, please do so, and let us know what you come up with. And if you'd prefer to pick components from Intel, AMD, Nvidia, or whoever instead of what we've used, by all means do so—it's your rig. Enjoy your build!

Alan Dexter is Maximum PC's *executive editor and a punisher of hardware. He's been a tech journalist for over 20 years, and has no problem upsetting the PC industry as a whole.*

↘ submit your questions to: comments@maximumpc.com

THE NEWS

Turing Goes GTX and Titan

Nvidia launches new GTX, RTX, and Titan cards

TITAN RTX
TITAN

Is this $2,499 beast the world's fastest PC graphics card?

NVIDIA'S INNOVATIVE ray-tracing RTX series has grown, with a new entry-level RTX 2060, and a top-end Titan RTX. It has also launched new GTX cards that use the new Turing silicon. It has effectively made two brands: the RTX series with ray tracing enabled, and the GTX series without.

The RTX 2060 is the card many have been waiting for. Nvidia's 60-series cards usually provide the best bang for your buck, useful given RTX pricing. The 2060 has 1,920 CUDA cores, 240 AI Tensor cores, and 30 ray-tracing cores. All down on figures for the RTX 2070, which has 36 ray-tracing cores. It'll have 6GB of GDDR6, a base clock of 1,365MHZ, and you'll need a spare eight-pin power plug.

First reports say that if you run *Battlefield V* with ray tracing enabled at 1080p, you'll see 65fps with DLSS turned on, and 88fps without it. Not too shabby. In general performance, it'll top a GTX 1070, and, depending on the game, just beat a GTX 1070 Ti. A GTX 1080 will outshine it a little, most of the time, though. The RTX 2060 should be available by the time you read this, at $349—a welcome drop from the RTX 2070's $499.

After much speculation about a possible 11-series, we now know we will get one, and the top models will use Turing chips, with the ray-tracing cores missing or disabled. It's not clear whether we'll still get the Tensor cores. It's these that are responsible for the clever upscaling using DLSS, and noise reduction. Leaving these running would give the 11-series a nice edge.

Unconfirmed, but pretty solid, rumor has it that the GTX 1160 will use the same Turing core as the RTX 2060, with the same basic specifications, which at least means the model numbers make sense. Assuming the same clock speed, we can expect the same performance without ray tracing, too. It's expected to launch with 6GB or 3GB of memory, as did the GTX 1060. More 11-series cards will follow soon—watch out for a GTX 1150 and GTX 1130.

Meanwhile, at the high end we have the mighty Titan RTX, which Nvidia claims is the fastest PC graphics card ever. This carries 4,608 CUDA cores, 72 RT cores, and 576 Tensor cores. These are paired to a whopping 24GB of memory, a big bonus for heavyweight productivity. Before you get too excited, it costs $2,499—$500 less than the old Titan V, but still. Performance is, as you might expect, tasty.

It's not marketed as a gaming card, but don't let that stop you—although gains over an RTX 2080 are not significant. You might like to consider overclocking a much cheaper RTX 2080 Ti instead, which will beat it. If you really want to chase those frame rates, double up with a GTX 1080 Ti SLI or NVLink RTX 2080 Ti. A pair of RTX 2080s will be a lot faster, as will a pair of 1080 Ti cards—and far less painful on your wallet. How about an NVLink Titan RTX rig? $5,000 of graphics cards will beat a pair of 2080s, but not by much, and whether you can actually see any difference when frame rates top 200fps is another matter. Even at 4K, this configuration can easily reach 150fps on some titles. You'll also start to hit serious CPU bottlenecks, and frame rate caps in game engines.

Nvidia has seen some push back over its RTX series. The technology is amazing, but the prices have been, too. It also needs decent game support, and software always lags behind hardware. Pushing RTX has had an impact on plain old rasterization performance. Nvidia's stock slide hasn't helped confidence, although there's a multitude of reasons for this, not least of which is the crash in demand for cryptomining hardware.

Things are going to get heated soon. AMD is preparing its Navi architecture, a new 7nm GPU. This follows a familiar pattern, offering an attractive price to performance ratio. Three new cards are expected: a Radeon RX 3080, 3070, and 3060. The 3080 uses a Navi 10 chip, with 8GB of memory, for $249. The 3070 uses a Navi 12 GPU, and should cost about $199, while the lessor 3060 makes do with just 4GB of memory, and it'll cost only $129. The new Radeon cards are due this summer.

How these cards perform running traditional rasterized games will be interesting. The competition they are aimed at is clear by the model numbers. If they can give Nvidia's expensive RTX series trouble, then at these prices, it could get ugly. In a good way. **–CL**

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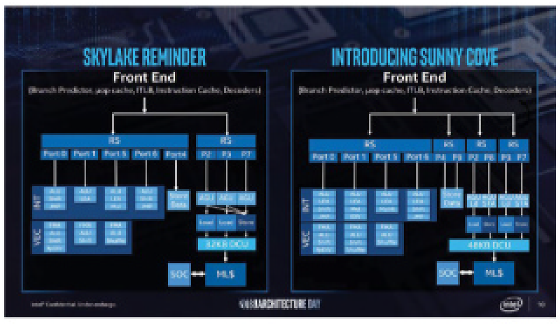


NO SLACKING IN CHIP WAR

10nm and 7nm chips this year, honest

INTEL MIGHT APPEAR to be having a tough time, with AMD's Ryzen taking big bites out of the PC market, but the tech giant has big plans for 2019. Of most interest is that we will finally get to see its new 10nm chip using the Sunny Cove architecture, Intel's first all-new design since Skylake in 2015.

We don't have many details, just a few slides shown at its Architecture Day event. It will have 50 percent more L1 cache, and "significantly" larger key structures, buffers, and so forth. It has a wider front end—that is, more paths—and can run two stores per cycle. It also gets an extra Address Generation Unit, a second Load Effective Address unit, 10 ports instead of eight, and a second shuffle unit, all adding up to more performance per cycle. We will also see the next generation of UHD graphics, hinted to be twice as fast.

Sunny Cove is unlikely to be completely 10nm; Intel has a modular system called Foveros that enables it to mix and match silicon. Eventually, Sunny Cove will appear in everything from Xeon server chips through to Core-brand mainstream parts. Also due this year from Intel is Cooper Lake, a successor to Cascade Lake.

The arrival of Sunny Cove can't come too soon, as AMD has confirmed a spring 2019 launch for its 7nm Zen 2 architecture. It's also modular, with 14nm elements to keep costs down. It's already out there as engineering samples; early reports claim around a 13 percent speed increase clock for clock on a 4GHz part.

Of more immediate interest are new Coffee Lake chips without integrated graphics: the Core i9-9900KF, i7-9700KF, i5-9600K, and i5-9400F. It's unlikely that Intel has a new wafer here, rather disabled the on-board graphics of existing chips, which does mean you can sell chips where the UHD graphics component has failed, but all else is well. The good news is that prices will undercut the current versions, and they will be able to cope with a little more thermal load. **–CL**

NEWSPAPERS HELD RANSOM

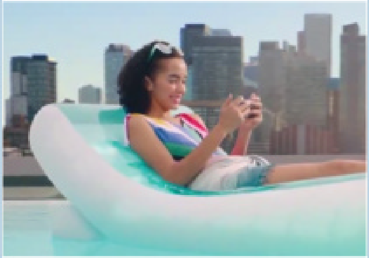
MALWARE MAKES YOUR PAPER LATE

A RANSOMWARE ATTACK hit the *Los Angeles Times* and other Tribune Publishing papers just before the new year. Only 15 percent of subscribers received their newspapers on time, and many editions were slimmer. It also disrupted west coast distribution of the *Wall Street Journal* and *New York Times*, among others. According to the group, it was "the biggest publishing disruption in decades."

The culprit is a piece of malware known as Ryuk, named after a Japanese manga character. It encrypts files, and demands payment in bitcoin for their release. Ryuk first appeared last summer, and was used in a well-planned series of attacks that netted a reported $640,000. This new attack originated outside the US; the Department of Homeland Security and FBI are investigating. Sophos Labs estimates that by the end of this year, ransomware will have cost the global economy over $11 billion. Along with hidden miner attacks, ransomware is the most "popular" malware out there. **–CL**

RECORD FINE FOR ISP

Fraudulent claims cost Charter $174 million



NEW YORK STATE and Charter Communication (which also does business as TWC and Spectrum) have reached a lawsuit settlement that will cost the ISP $174.2 million. Charter was accused of fraudulent, misleading, and consumer-hostile actions. At one point, it was even given 60 days to stop operating in the state. It is the biggest ever payout to consumers by an ISP. Charter was said to have "denied the customers reliable and fast Internet services it had promised." Advertised speeds were only reached 60 to 70 percent of the time. The hardware the company distributed was deficient, and network capacity not maintained. Charter also used hardball tactics with Netflix, and other streaming services, leading to frozen screens, extended buffering, and degraded video quality. $62.5 million of the fine will be used to compensate customers directly. **–CL**

Tech Triumphs and Tragedies

A monthly snapshot of what's good and bad in tech

TRIUMPHS

3NM CHIPS PLANNED
TSMC is to build the world's first 3nm foundry for $19.5 billion—we can expect to see the results in 2022.

FORTNITE FORTUNE
Gamer Tyler Blevins earned nearly $10 million last year through Twitch and YouTube.

ULTRA SHORT THROW PROJECTORS
LG's new CineBeam Laser 4K can give a 90-inch image at just two inches from your wall.

TRAGEDIES

DRM DOES HIT GAME PERFORMANCE
Proof emerges that Denuvo does impact games—frame rates and load times are slower.

CLASSIC FLOP
Sony's retro PlayStation Classic isn't selling well; blame falls on the poor games bundle.

RIP DR. LARRY ROBERTS
A founding father of the Internet, he laid out the original network, and introduced packet switching.

AI Breathes New Life into Old Games

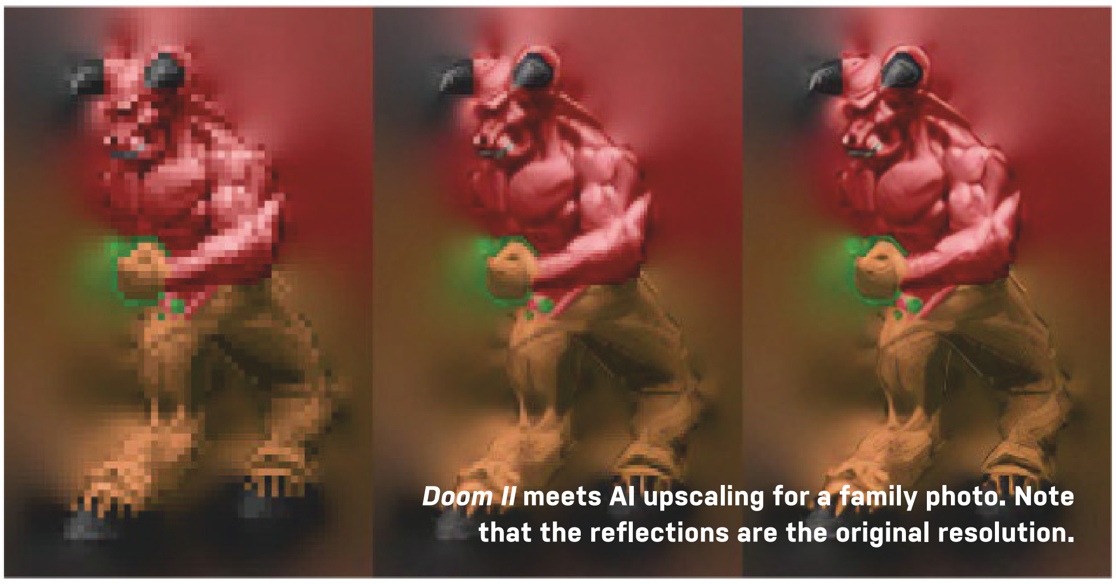
ONE OF AI'S NEAT ABILITIES is to intelligently upscale graphics, extracting extra detail from low-res images that is impossible using traditional scaling. It was only a matter time before the modders took an interest. A project by DassiD is developing a high-res graphics update for *Morrowind,* and modder "hidfan" is working on *Doom II.*

The *Doom* project uses tools from Nvidia's GameWorks, and a touch of Topaz Labs' AI Gigapixel. Graphics are upscaled eight times using two methods, merged, then downscaled by half with bicubic interpolation to remove noise, then downscaled by a half again using nearest-neighbor supersampling to retain sharpness. There are still issues, particularly with transparencies. It also requires some manual cleaning up to remove AI artifacts. *Doom II* has never looked so good, though.

The *Morrowind* update uses Enhanced Super Resolution Generative Adversarial Networks, a similar process that creates detail using several different methods (it gets complicated). The final graphics have been rendered at four times the size.

Significantly improving an old game's graphics isn't easy. Previously, it required access to the original resources, along with permissions. Then a new graphic pack has to be made, new textures, models, and more. A time-consuming business.

Using AI means all you need is a copy of the game to work from, little or no original content required. You don't get all the modern bells and whistles—shadows, reflections, and so on—but you get a respectable upgrade. Retro gaming is big, and AI can breathe new life into blocky, low-res worlds relatively easily. Good work. **–CL**


***Doom II* meets AI upscaling for a family photo. Note that the reflections are the original resolution.**

Steam Drops XP and Vista

Starting this year, Steam will no longer be an option if you're running Windows XP or Vista. Understandable really, as they've lost Microsoft support, and Valve's own figures put their usage at under one percent.

Paradoxically, Steam's support for old games is impressive. It has modified many to keep them available, such as 1995's *Ultimate Doom,* the re-release of 1993's original with an extra level. It appears that games have a longer shelf life than the OSes they were designed to run under. XP is the most stubborn survivor; its use worldwide is over four percent (of the machines online). Not bad for an OS launched in 2001. **–CL**

Facebook Knows Where You Are

If you turn off Location History on Facebook, you'd expect it not to know where you are. It transpires it still does, more or less, as it monitors your IP address. This is odd, as on the Facebook Business blog, it states people "only see ads based on their recent location if location services are enabled on their phone." Not true. On its "How Facebook ads work" page, it's more honest, saying it uses where you go online to track you. This came to light when Aleksandra Korolova, a university science professor, avoided sharing any location data, yet still got location-based ads. Facebook has since admitted there's actually no way to turn off location-based ads. **–CL**

03
TIBOR PRINT DRESS
SOURCES OF INSPIRATION ARE OFTEN ACQUAINTED WITH THE PAST, BUT NEVER RETRO, AND LED BY A THIRST FOR KNOWLEDGE OF ART, DESIGN, AND DANCE.

APPLE'S BENT iPAD PROS

The device is more flexible than you think

THE NEW APPLE iPAD PRO is a svelte thing, thinner than ever, with a minimal bezel around the display. As sales started in December, an issue emerged: There has been a number of reports of many box-fresh machines being slightly bent, with a small, but perceptible, kink in the middle. Apparently, according to Apple, the warping is caused during the cooling process of the plastic and metal chassis. It does not affect function.

The bend occurs at a weak spot at the middle, where there is a small hole for the mic on one side, and the induction charger for the Apple Pencil on the other. It doesn't help that the glass screen is rather thin, too. Destructive tests show that it takes little pressure to fold one in half. You'll have to be extra careful not to stress the frame during transport.

What can you do if your iPad Pro isn't flat? Well, Apple doesn't consider the bend to be a defect, so will not replace it. You can return it for a replacement during Apple's standard 14-day returns policy. If that's elapsed, if you admit to causing the "damage" yourself, you can get the machine replaced under Apple Care+, but it'll set you back $49, and use one of your accidental damage deductibles. Otherwise, you'll have to live with it.

A small bend would be easier to dismiss if this was a cheap thing, but iPad Pros start at $799. Apple has an enviable reputation for attention to detail, and its customers expect a lot from the company. This issue was undoubtedly noticed during manufacturing, and Apple's decision to ship anyway has had the forums fizzing with indignation. We've been here before. In 2014, a similar problem beset the iPhone 6, which Apple was fully aware of before release. Eventually, the company agreed to replace them under warranty. We shall see if it will acquiesce again. **–CL**

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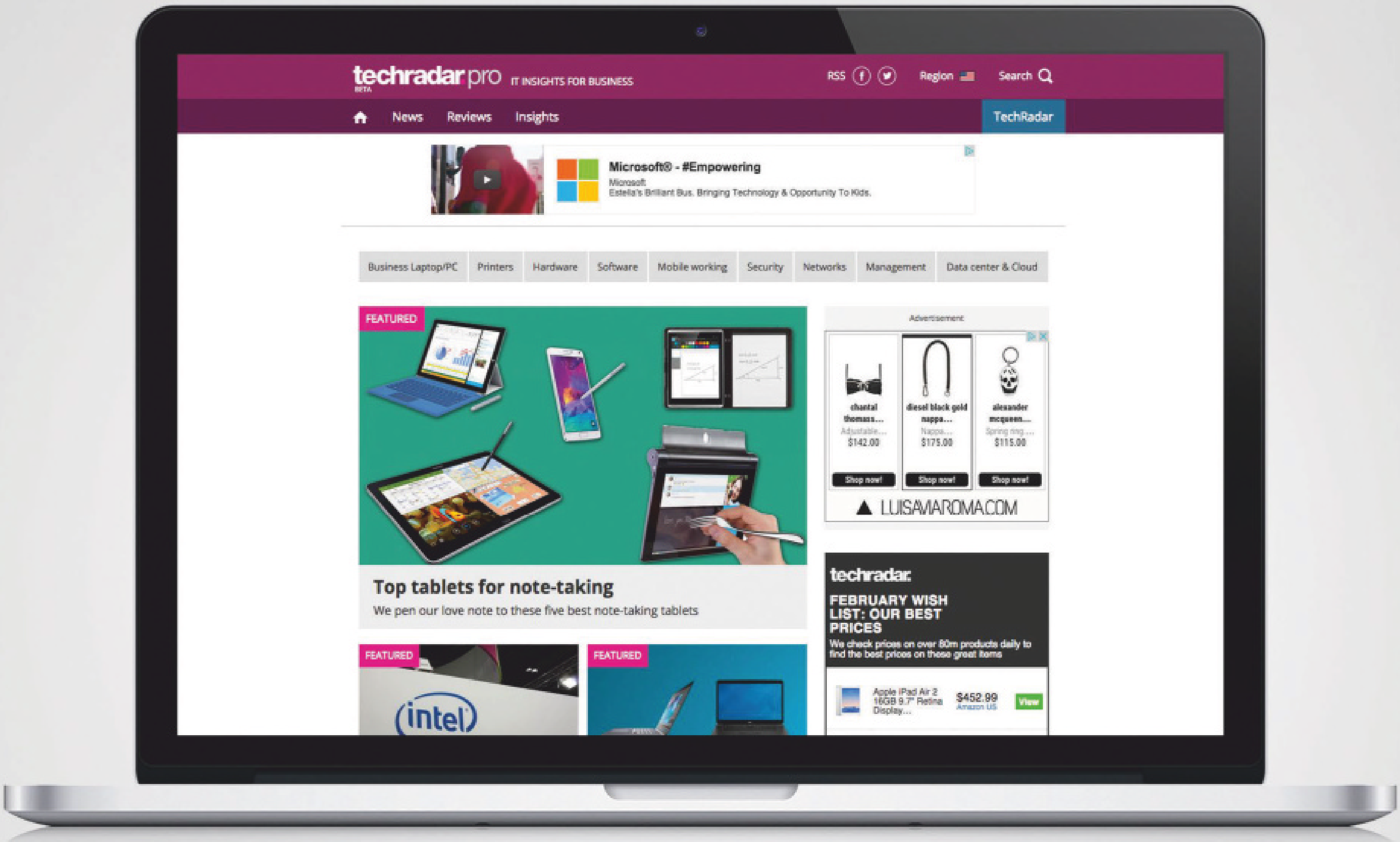
IT INSIGHTS FOR BUSINESS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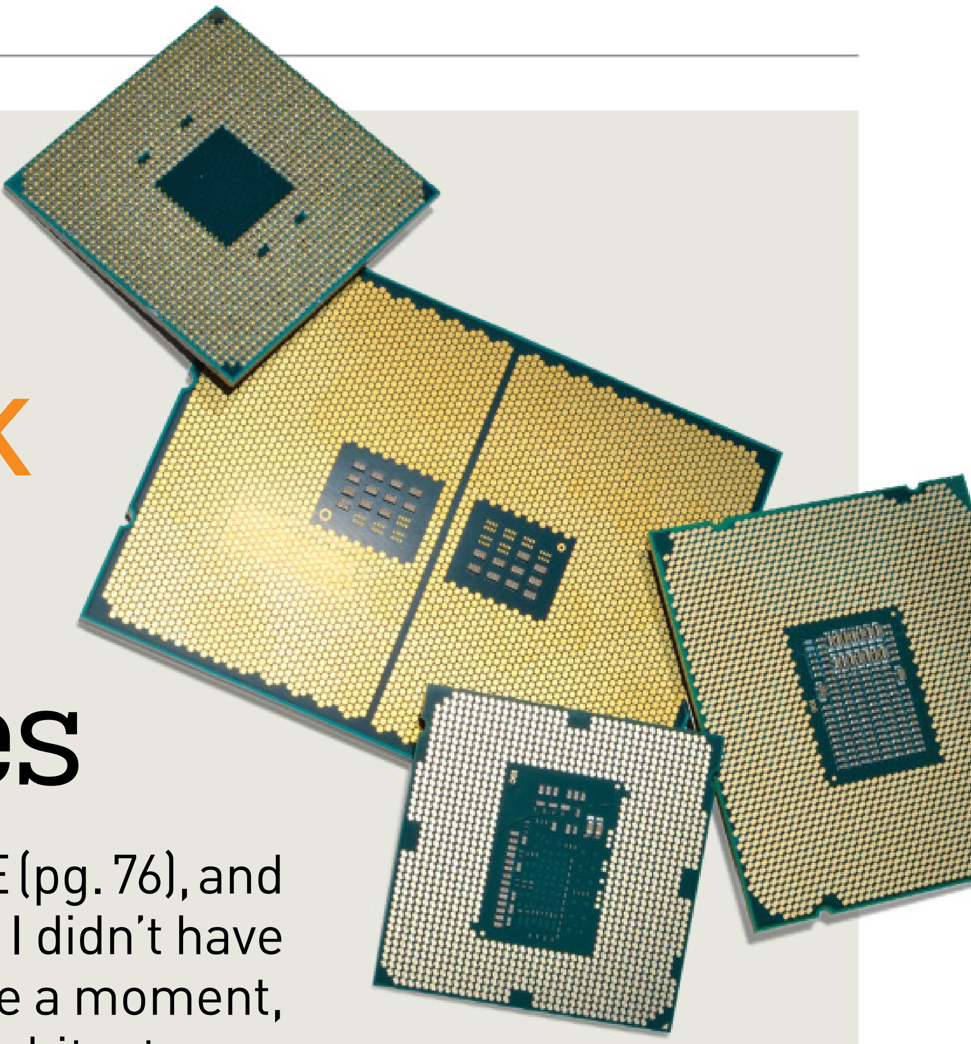
Jarred Walton

TECH TALK

The Folly of Counting Cores



I'VE BEEN REVIEWING the Core i9-9980XE (pg. 76), and there's a lot of supplementary material I didn't have space to discuss. So, if you'll indulge me a moment, let's talk a bit more about CPUs and architectures.

What's the best processor on the planet? You might think there's a simple answer, but it depends on what you plan to do. Just about any modern CPU is "fast enough" for general applications, and upgrading other components might be more worth your time. But let's just focus on CPUs for now.

The past two years, AMD and Intel have pushed the boundaries on core counts to potentially obscene levels. AMD's updated second-gen Threadripper processors now offer up to 32 cores/64 threads in a single package, and at first you might be tempted to take the plunge. But when you start digging into the benchmarks, things get a lot more complex. Some heavily threaded workloads have excellent performance on Threadripper 2990WX, others do better on a Threadripper 2950X, and some even perform best on a Ryzen 7 2700X. What's going on?

It goes back to AMD's Zen architecture and how it chose to scale from quad-core up to 64-core CPU packages. Socket TR4 may look like Epyc's socket SP3, but a bunch of the pins are unused. Epyc CPUs have octal-channel memory, but Threadripper is limited to quad-channel. The second-generation WX parts have four CPU packages—basically four Ryzen 7 processors—but two of the CPUs have to talk to system RAM via the memory controllers on the other chips. At the same time, AMD altered the die-to-die Infinity Fabric, and cut the bandwidth in half (from 50GB/s to 25GB/s).

Combined, these changes cause much higher latencies for some workloads, and the result can be disastrous. In fact, it can be so bad that AMD even provides a way to disable the extra cores, effectively turning the 2990WX into a 2950X. But what happens if you leave all the cores enabled?

In testing, applications including video encoding, 7-zip compression, web browsing, photo editing, and more tend to underperform thanks to the 2990WX's design. Often, the 2950X beats the 2990WX, despite having half as many cores. Most games also perform better on the 2950X, and better still on a Ryzen 7 2700X—and Intel's CPUs take top honors. In other words, more cores aren't always better, and in some cases, they can be substantially worse.

Other applications that make good use of AVX instructions, such as video editing and scientific computing, also favor CPU architectures with better AVX support. Despite their core deficit, Intel's Skylake-X CPUs do very well in Handbrake x265 and y-cruncher, thanks to their use of AVX512. Other applications favor higher clock speeds and lower latencies. Most games, for example, provided you're using a fast enough graphics card (for example, a GTX 1080 Ti or RTX 2080, or above), run best on a Core i9-9900K. Numerous professional apps such as AutoCAD, Solidworks, Maya, and more favor Intel's Coffee Lake processors, in part because a professional GPU like a Quadro P6000 offloads a lot of the work.

It may not be a huge performance deficit, but at roughly six times the cost, you might mistakenly think a Core i9-9980XE would be clearly better for professional use than a Core i7-8700K. Sometimes it is, sometimes it isn't—there are times when the i7-8700K is up to 15–20 percent faster. I suspect the future 28-core X-series CPU will follow a similar pattern. It will generally perform worse in games and certain professional applications, because it will of necessity have lower clock speeds, and its mesh network will further increase latencies for memory accesses.

Trying to compare CPUs on core and thread counts is as useful as comparing the number of pins.

Elsewhere, however, core and thread counts reign supreme. Cinebench and several other CPU-based 3D rendering applications all scale extremely well with additional cores. A Threadripper 2990WX is about 40–50 percent faster than a Core i9-9980XE in Cinebench, POV-ray, and Corona, for instance.

In short, more than ever before, it's important to know your workloads as well as the CPU and platform architectures and features. Only then can you determine which CPU is best, and it may not be the most expensive part, or the one with the most cores. For a lot of people, including even many professionals, the mainstream AMD and Intel CPUs are the best overall options—core counts be damned.

Jarred Walton has been a PC and gaming enthusiast for over 30 years.

THE LIST

THE EIGHT CRAZIEST CRYPTOCURRENCIES

8

INITIATIVE Q

Sold on the promise of free money, we'd wager our bonus that 20,000 Q never actually equals $20,000. Just a hunch. http://initiativeq.com

7

DOGECOIN

Proof if it were needed that a (mercifully) long-dead meme can live on in coin form. A top 30 one, at that. http://dogecoin.com

6

DENTACOIN

Are you a dentist? Well, have we got the cryptocoin for you! Yes. It's Dentacoin. And it's specifically for dentists. http://dentacoin.com

5

COINYE

What might have been, had Kanye's lawyers not squashed this unauthorized Yeezy currency? We'll never know. www.coinyecoinsglobal.com

4

UNOBTAINIUM

Deliberately rare, with 250,000 coins available to be mined over the next 300 years. That's quite the power bill. www.unobtanium.uno

3

USELESS ETHERIUM TOKEN

Purposefully worthless, the initial offering somehow still made over $300,000. http://uetoken.com

2

GARLICOIN

As if Reddit hadn't done enough bad with Dogecoin, here comes a Litecoin-linked currency based on garlic bread. Of course. http://garlicoin.io

1

TRUMPCOIN

See also a raft of other 'hilarious' political currencies, including PutinCoin, Billary Coin, Ron Paul Coin, and the Mao Zedong. www.trumpcoin.com

Alex Campbell

OPEN SOURCE

Nvidia Gives the Gift of PhysX

IN DECEMBER, Nvidia announced that it was open-sourcing its PhysX physics simulation engine. Sure, we all love PhysX effects in games, but Nvidia did it for scientists and engineers as much as game developers.

Accurate, quick physics are the hallmark of modern games. While you might think game physics are simply the trajectory of an object in space, the real meat and potatoes of game physics are when things touch. When objects touch, Newtonian physics can give us a pretty good idea of where they are going to go, and how fast they'll move. In simple terms, you can think of objects as simple as pool balls on a table, or as complex as a car in *Rocket League*.

While it can operate on a CPU, PhysX is designed to do thousands of high-school physics problems in a massively parallel way on the GPU. Think of it as multithreaded physics calculations across hundreds of cores, because that's exactly what it is. As anyone who's shot a Kerbal into orbit will attest, physics can be hard, and performing those calculations across hundreds of cores on your GPU instead of the four to eight on your CPU has obvious advantages for performance.

As great as PhysX is, it was never designed to simulate real-world physics with precision beyond what you'd experience in a game at 60–144Hz. Nvidia's API documentation of PhysX says, "PhysX is best suited for quasi-real time interactive 3D applications where performance and scalability are more important than precision." If that sounds a little wonky, it is. In a game, you need to be able to predict where an object might be according to a Newtonian world before the next frame is rendered. If you're rendering at 60Hz, that means the PC has 1/60 of a second to figure out where that broken shard of glass has to be. For a high-end GPU, that's plenty of time, but it's slow compared to the real world, where time is infinitely divisible. Nvidia has its eyes on machine learning and driverless cars, and to get PhysX into those worlds, it needs to think beyond the gaming level of performance.

©NVIDIA

These days, PhysX is being used for machine learning as much as games.

In a gaming development paradigm, licensing the PhysX API to developers with legal staff and training resources might make sense, but like Microsoft, Amazon, and Red Hat, Nvidia's big money is made in the cloud and compute applications. In a data-driven world, licensed closed-source software can't scale like open-source can. Open-sourcing the engine also means that features can be added by the community, so the engine can do more stuff on different hardware setups. Developers also don't have to worry about violating the PhysX end user license agreement.

For gamers, it also has an interesting consequence. As Nvidia had control over the source, it had no incentive to write instructions in PhysX to make use of resources on AMD graphics. With the code wide open, it could be possible to get PhysX to work with AMD cards, if AMD (or anyone else) modifies PhysX to use AMD-specific instructions, resources, and optimization instead of Nvidia's. Before you get too excited, keep in mind that Nvidia has spent a decade optimizing PhysX for Nvidia hardware, so it'll probably take more than a couple lines of code to get PhysX to work at the levels you'd expect on an AMD GPU.

It's pretty awesome that Nvidia's powerful tool is everyone's powerful tool now, and the potential for interoperability with AMD hardware is only one part of it. If only Microsoft would let DirectX come to Linux.... One can dream.

Alex Campbell is a Linux geek who enjoys learning about computer security.

HEAD TO

BY **JEREMY LAIRD**

High Refresh vs. High Dynamic Range vs. High Resolution

The modern monitor market is marvelous: 240Hz refresh, resolutions of 4K and beyond, and latterly eye-popping HDR capabilities. But all three in a single monitor? That's an awfully big ask. And it's an awfully big ask because upping the refresh and resolution, or adding HDR (high dynamic range) capabilities, all increase the required bandwidth. You simply can't have the highest available resolution, the fastest refresh, and HDR all in one monitor. Something's gotta give. But what should that be? It all depends on your chosen remit.

ROUND 1

Games

Pumping more pixels has always been a problem when it comes to gaming. Higher resolutions put more strain on your graphics subsystem. And that means lower frame rates. When nearly all monitors ran at 60Hz, however, that often didn't matter. If a higher resolution dropped your frame rate from 120fps to 70fps, you wouldn't actually be able to see the difference on a 60Hz panel.

But now that screens with refresh rates up to 240Hz are available, it's a whole different ball game. Even today, the graphics card that can drive all the latest games at well beyond 100Hz at 4K doesn't exist. So, if you want super-slick and responsive gaming, you want a high-refresh panel with a middling pixel count. Something like 1440p, in other words, rather than 4K.

As for HDR, game support is limited. But where it is available, HDR can look fugging fantastic. So, if you're looking for a long-term solution, an HDR panel is certainly appealing. A true HDR panel will, of course, guarantee strong performance in terms of contrast and color depth. That's a plus for SDR or standard dynamic range games, not just titles that support HDR.

Winner:
Refresh rate plus a little HDR

ROUND 2

Productivity

It's surprising how sweet high refresh rates are even for the simplest of day-to-day computing activities. Everything feels more responsive, immediate, and natural at higher refresh rates.

Despite that, we wouldn't prioritize high refresh over resolution for productivity. More often than not, more pixels are of greater value for getting stuff done. For starters, you can see more, which is not only more practical and ergonomic, in the sense that you can see more of a given webpage, or view multiple pages and documents at the same time, but also critical when it comes to the likes of editing images and video at full resolution. For that, there's no substitute for more pixels. Of course, high resolution at any screen size also results in a tighter pixel pitch. That means a sharper image, crisper fonts, and all that jazz.

If more pixels are nice, what about HDR? It's not an obvious win for productivity, especially as most HDR monitors do horrible things to SDR content when running in HDR mode. On the other hand, a monitor capable of one of the more demanding HDR standards will have an inherently high-performing panel.

Winner:
Resolution

ROUND 3

Movies and Video

You could argue that 4K content is thin on the ground, as the majority of what you might call legacy content isn't available in 4K, but pretty much all major new movies are now released at that resolution. Likewise, streaming services such as Netflix and Amazon are making more and more 4K content.

You could say the same of HDR, but more so. Only a subset of 4K content is available in HDR. However, a screen with HDR support is more capable, thanks to greater contrast and color performance. That makes SDR content look better, too. A screen with higher resolution than the source content doesn't help at all. Indeed, interpolating a low-res image on a higher resolution panel typically delivers a worse result than rendering the same image at native resolution.

As for high refresh rates, they're irrelevant to nearly all video content. Few movies are captured in anything even approaching high frame rates. So-called High Frame Rate, or HFR, movies—like *The Hobbit*—are just 48fps. Streaming content recorded at 60fps is becoming more common, but either way, a standard 60Hz monitor has a sufficiently high refresh rate.

Winner:
Resolution and HDR

HEAD

From left to right: **4K and 32 inches is the value sweet spot; gaming panels with higher refresh rates are pricey; true HDR with local dimming is insanely expensive.**

ROUND 4

Value

For reasons that elude us, high refresh monitors remain very pricey. We suspect that the fact it's perceived as a gaming-centric feature encourages screen makers to price their high refresh models up in the stratosphere. Whatever, it makes for poor value for anything but a dedicated gaming panel.

On the other hand, 4K monitors are now genuinely affordable. We're not just talking about 4K screens with the cheapest of TN panels. In the last year, the number of 4K models with VA and IPS panels for around $300 has increased dramatically. A 32-inch 4K monitor with a good quality panel from a decent brand for $350? Now that is an appealing value proposition. Other than serious gamers, anyone on a limited budget will get much more overall bang for their buck going for more pixels than higher refresh rates.

HDR is trickier. Much depends on how you define HDR. True HDR displays with local dimming or, even worse in terms of cost, an OLED panel, remain very expensive. Pseudo HDR monitors with wider color spaces, though, aren't necessarily much more expensive, but they aren't necessarily much better than a conventional SDR display.

Winner:
Resolution

ROUND 5

Virtual Reality

OK, VR feels pretty dead, what with the Oculus Rift 2 being canceled, and the founder of Oculus VR, Palmer Luckey, recently implying that people didn't want VR even if it's free.

But it's still an intriguing technology, and one we can't entirely dismiss. But of refresh, resolution, and HDR, which is the most important for virtual reality displays? The short answer is all of 'em. But some are more important than others. The most important is refresh rate. You need at least 90Hz to have a solution that feels reasonably responsive. Without that, the experience is sluggish, unconvincing, and even nausea-inducing.

Resolution matters, too. With the display filling your field of view, you need a lot of pixels to avoid the screen door effect—in fact, more than any commercial VR headset offers. As for HDR, that too would be a requirement for a truly convincing VR world. It isn't quite as important for enabling a good basic experience, though, and it's probably the least problematic in terms of implementation in a VR context. So, odds are, by the time the res and refresh barriers are hurdled, HDR will be an easy add-on.

Winner:
Refresh then resolution

And the Winner Is...

Taking your pick between resolution, refresh rates, and HDR support is all about remit. Heavy gamers will put a major premium on higher refresh rates, even though they come at a cost. For anyone else, resolution should be their priority in most cases. It gives you more screen real estate, nicer fonts, sharper images, and the ability to see larger images and video files in all their glory.

Money no object, why not go for both? Because there's no such thing as a 5K monitor with 120Hz-plus refresh. Even 4K monitors with triple-digit refresh have only very recently become available at a painful price.

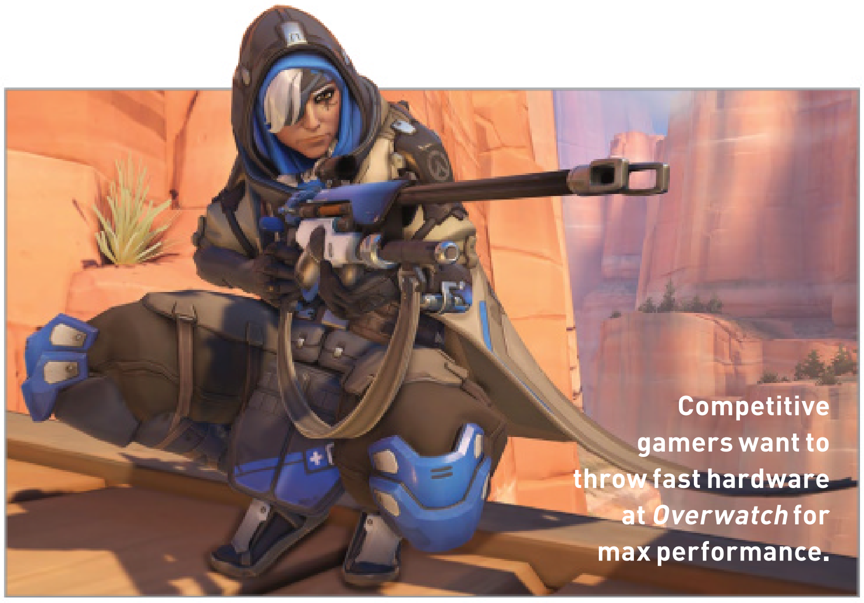
HDR is more complicated. Partly that's because of the wide range of HDR standards, some of which deliver on the premise much more effectively than others. It's also because of the patchy content availability and problematic implementation in the Windows OS.

Having all three would be nice, but if there can be only one, more pixels deliver more all-around utility more often than the alternatives. ⏻

DOCTOR

THIS MONTH THE DOCTOR TACKLES…

> Gaming Upgrades
> Geriatric Gear
> Power Struggles



Competitive gamers want to throw fast hardware at *Overwatch* for max performance.

Overwatch Upgrade

Dear Doctor, I have a Dell OptiPlex 7010 with a Core i5-3470 CPU, 16GB of RAM, and a GeForce GT 730. Recently, I started playing *Overwatch* more competitively, and I'd like to upgrade my setup for better performance. I plan to add a 1080p monitor with a 144Hz refresh rate.

Right now, my PC can handle *Overwatch* at a little over 60fps using the lowest detail settings. Should I upgrade to a used Core i7-3770K and a GeForce GTX 1050 Ti, or should I build a completely new system with more modern components? **–MrStrawCloud**

THE DOCTOR RESPONDS: By design, *Overwatch* runs well on mainstream hardware. But if you're playing it competitively, you want as much performance as possible. An old Core i7-3770K and GeForce GTX 1050 Ti would certainly be an improvement over your current hardware. Consider, though, that Intel's Core i7-3770K is more than six years old, like your Core i5-3470.

While the upgrade you're proposing does satisfy *Overwatch's* recommended specifications, building a new platform with modern, mainstream components will give you a much better experience. A Ryzen 5 2600X offers six cores with multithreading technology, capable of working on 12 threads simultaneously. For a few bucks more, the Core i5-9600K is an even better six-core gaming CPU. Both models boost beyond 4GHz and are easily overclockable through adjustable ratio multipliers. AMD bundles a heatsink and fan for cooling its CPU; Intel does not. Either way, upgrading to an aftermarket thermal solution is a good idea if you plan to overclock.

As for graphics, buy as much horsepower as you can afford. It's true that FHD isn't a particularly demanding resolution these days, but you want a card capable of triple-digit frame rates to exploit the benefits of a 144Hz panel. The Doc wouldn't go any lower than a GeForce GTX 1060 6GB or Radeon RX 580. If you have the budget for a GeForce GTX 1070 or Radeon RX Vega 64, those are even better options.

Don't forget to factor in the other components you need for a balanced configuration, such as a high-quality power supply, solid-state storage, and plenty of DDR4 memory. Your motherboard matters, too. Overclocking Intel's K-series processors requires an enthusiast-oriented Z390 or Z370-based platform.

Now, here's the irony of sinking big bucks into a brand new build: Competitive gamers dial down their detail settings to maximize frame rates and minimize the game's simulation rate. Giving up gorgeous graphics for the sake of lightning-fast response helps stop hardware from getting in the way of your talent. From there, practice, practice, practice.

Aging Hardware

Hello Doc. I'd like to remain anonymous, but still have a couple of questions. First, my rig is an old Dell Vostro 460 with a GeForce GTX 750 Ti and some other parts. Are you able to track down the rest of the specs? I'd like to maximize the performance of this system without causing it to fail prematurely. Then, at some point in the future, I'd like to copy all my files over to something new.

On that note, when I am ready to build my next gaming rig, would you recommend a custom water cooling loop or a closed-loop AIO? **–Anonymous Reader**

THE DOCTOR RESPONDS: The Vostro 460 was a 2011-era system based on Intel's H67 platform controller hub. It came with Core i3, Core i5, and Core i7 processor options, so check out the Device Manager or System

↘ submit your questions to: doctor@maximumpc.com

Properties in Windows for specific CPU information. Nvidia didn't launch its GeForce GTX 750 Ti until 2014, so you must have upgraded the Vostro's graphics subsystem at some point. Dell's motherboard features four memory slots that support anywhere from 1GB to 16GB of DDR3-1333. Again, the System Properties (or "About Your PC" in Windows 10) pane will tell you how much RAM is installed.

There isn't much you can do to change the Vostro 460's performance. Its H67 chipset limits processor tuning options, and Dell's 350W PSU keeps you from adding a more potent graphics card. An overclocking utility like MSI's Afterburner may help squeeze a few more frames per second out of mainstream games, but don't expect big gains from a system that was designed to serve as a business desktop, not a gaming PC.

When it comes time to build something new, choose components that complement each other. Your cooling requirements are determined by the hardware you install, so there's little reason to drop an expensive water block on to a Core i5 or Ryzen 5 CPU. On the other hand, a flagship Core i9 or Threadripper practically begs for a custom loop. As always, balance is the name of the game. Don't overspend on cooling if that money could be better used on a larger SSD or faster graphics card.

Strange Behavior

Hi Doc, I think I have a brain teaser for you. I just bought a new PC from one of the companies that lets you pick all the components and then they build it for you. My old PC was also from them and it ran quite nicely. The new one does, too. The problem I'm having is how it powers up.

First, the specs. It hosts an Intel Core i9-9900K CPU, an Asus TUF Z390-Pro Gaming, a 512GB Samsung 970 Pro M.2 PCIe SSD, a 1TB Samsung 860 EVO SSD, a GeForce GTX 1070 graphics card, and an 850W Be Quiet! Straight Power 11 PSU.

With all my previous PCs, I used battery backup that the system itself, monitor, and speakers all plugged into. I used the UPS's power button as a master switch to turn everything on and off at the same time. After setting this machine up similarly, I went into the BIOS and set the AC restore mode to power on the PC. I turned the UPS on and watched as the motherboard started its own boot process (status LEDs started to light up). But after a few seconds, the board powered back down. A few seconds later, it powered back up again and continued through the boot process all the way to Windows with no problem. I repeated this a couple of times just to make sure the result was consistent. As a troubleshooting measure, I disabled the BIOS setting to boot up after AC power loss, used the button on the case after the UPS was turned on, and observed the same behavior yet again.

My next step was to keep the UPS on and shut down Windows, leaving line power supplied to the PSU. When I hit the case's power button, my PC booted straight to Windows without restarting. So long as the motherboard doesn't lose AC power entirely, this PC seems to boot up fine. Conversely, shutting it down and disconnecting mains power (by unplugging it or turning the UPS off) causes those multiple boot attempts.

I'm not sure if it's the PSU or mobo causing interrupted power after the UPS is turned back on, but it can't be good for my components, right? Have you heard of anything like what I'm describing?

–Gerry Exstein

The Core 2 Extreme QX9650 is over 11 years old. Retire it and move legacy software to a VM.

THE DOCTOR RESPONDS: Because the Doc has not seen this behavior in his lab, he escalated your question to the folks at Falcon Northwest, who build high-end PCs for a living. The technical team over there reported back that the behavior you're seeing has been observed on multiple motherboard models from multiple vendors. There is no official explanation for it, and the latest ATX specification makes no mention of why it'd be necessary. Adding to the mystery, the symptoms you report have been known to change after a BIOS update.

Right now, the working theory is that losing AC power requires the motherboard to recalibrate its power signals and clock rates. This process is intentional and should not cause any damage. More than anything, it's an inconvenience. Some boards incorporate documented options to bypass the calibration, though doing so may affect your ability to overclock. EVGA specifically reported adding a "ClockGen Switch Mode" to its old P55, H55, and H57 models, which kept from them from restarting twice.

Digging in to the TUF Z390-Pro Gaming's documentation, it appears there's an item under the "Boot" menu called "Next Boot after AC Power Loss," which appears only if you have "Fast Boot" set to "Enabled." Asus's description of the option isn't worded very well, but "Accelerates the boot speed on the next boot after an AC power loss" makes the Doc think an easy solution may be available.

SSD on Windows XP

Doc, I realize I should have upgraded from Windows XP a long time ago, but the legacy software I use for work makes stepping up to Windows 10 (or even 7) impractical at best and almost impossible in the worst case.

I want to migrate my well-oiled system from an aging Lian-Li PC-60 Plus case into a more accommodating Be Quiet! Silent Base 601, and perform a few upgrades in the process. Among them would be to replace a WD 640GB Black spinner with a Samsung EVO 500GB SATA SSD as my primary drive.

The problem is that I don't think Windows XP has native support for SSDs. My system consists of a Gigabyte EP45-UD3P motherboard with a Core 2 Extreme QX9650 CPU, 4GB of RAM, an Nvidia GeForce GTX 560 Ti (to be replaced by an EVGA GeForce GTX 1060 SSC 6GB), a Corsair 850W modular PSU, and a Hyper 212 Evo heatsink that I plan to replace with a Corsair H105 all-in-one cooler.

The upgrades I listed were accumulated over the past couple years and are driving my desire to make this move. But the need to keep my legacy software available has prevented me from swapping components out. What would the Doctor suggest to help me get the SSD properly cloned as my primary drive?

–Phil Griffith

THE DOCTOR RESPONDS: XP will run without issue on an SSD. What you'll lack is support for the TRIM command, leaving the drive's built-in garbage collection algorithms to clean up partial blocks of data. This requires free space to operate, so buy a drive that's large enough that you won't fill it up.

A more elegant option would be to install a modern operating system and virtualize Windows XP under it using Hyper-V. The hypervisor is built into Windows 10, after all. Migrating your Windows XP VM to other systems would become much easier, and you'd simultaneously open the door to a host of practical hardware upgrade options.

BUILD A $999 GAMING PC

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ADATA
Ultimate Solid State Drive
SU630
RYZEN
230V

How close can we get to that 1K sweet spot, and what kind of PC does it get you?

ONE OF THE MOST common questions we get asked by folks is how much they should be spending on their next rig. It's a tricky one to answer. We've mentioned in the past how the value of the dollar changes depending on the total available budget for a system, but there's also a secondary factor you need to consider, and that's one of price to performance. Once you get past a certain price point, the amount of performance you get for the dollar inevitably begins to drop—in some cases, quite dramatically.

Take AMD's Threadripper 2970WX, for example. At stock, it scores a fairly heady 4,407 points in Cinebench R15. Compare that to a Ryzen 5 2600's 1,274 points, and that's a 246 percent increase in performance. However, each dollar you put into the 2970WX effectively gains you 3.39 points, against the 2600's 6.71 points per dollar, which is an increase in value of near enough 98 percent.

So, this is our "sweet spot" build. The rig of choice for those trying to get the most bang for their buck today. It's not the most value-oriented system out there, nor does it cater toward the high end, but if you're trying to make every single dollar count, this is a really good place to start. *–ZAK STOREY*

INGREDIENTS

PART		PRICE
CPU	AMD Ryzen 5 2600	$160
GPU	XFX Radeon RX 590 8GB Fatboy OC+	$280
Mobo	MSI B450M Mortar	$95
Memory	**16GB** (2x 8GB) **HyperX Predator @ 3,200MT/s**	$157
SSD	480GB Adata SU630 2.5-inch	$58
Cooler	**Stock** (AMD Wraith Stealth)	$0
PSU	500W Cooler Master MasterWatt Lite	$50
Case	Thermaltake Level 20 VT	$99
OS	Windows 10 Home (64-bit)	$100
Total		**$999**

PRICES CORRECT AT TIME OF PRINTING.

PROCESSOR

AMD RYZEN 5 2600

$160

WHAT AMD HAS DONE to the CPU market is nothing short of incredible. The value proposition Ryzen represents is staggering, and nowhere is this more apparent than with the Ryzen 5 2600. Six cores and 12 threads for $160 is simply amazing. Couple that with it being the best value-for-money processor in our testing, plus the fact it's unlocked for some serious overclocking, and you're quickly on to a winner.

In-game performance has increased by leaps and bounds since first-generation Ryzen as well. This is mostly down to memory latency improvements and added game support for the new architecture.

GRAPHICS CARD

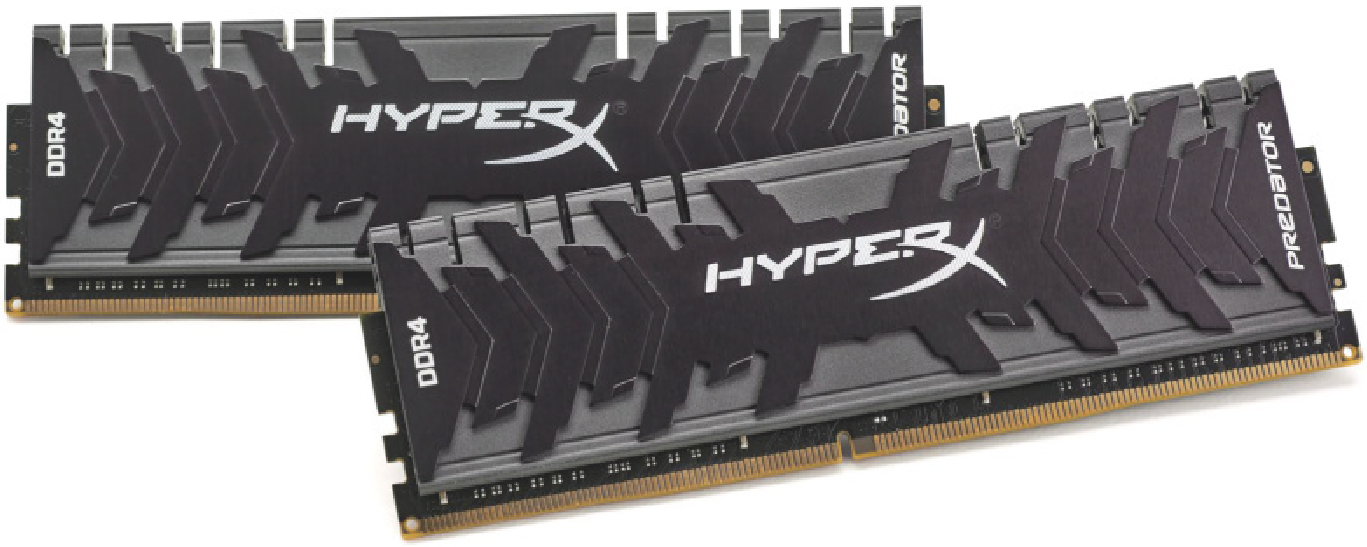
XFX RADEON RX 590 8GB FATBOY OC+ $280

WE MAY HAVE GIVEN the RX 590 a hard time over the previous few issues, but that's only because it's a refresh of a refresh, and like a disappointed parent, we just want AMD to do better. If you're building a brand new rig, however, it's hard to argue with Team Red's pricing on this GPU. In fact, it's the best bang-for-the-buck GPU we've found. XFX's iteration, the Radeon RX 590 8GB Fatboy, is a clean-looking piece of hardware. Perhaps a bit garish, with its faux carbon fiber and bright red fan stickers, but of the two 590 options we have (this and the baby blue monstrosity from Sapphire), this is our preferred choice.

MEMORY

16GB *(2x 8GB)* HYPERX PREDATOR @ 3,200MT/S $157

RYZEN THRIVES ON high-frequency memory, and for now, the sweet spot for that certainly seems to be the 3,200MT/s mark. Although, admittedly, this isn't quite the cheapest kit out there, we feel that 16GB—at least for now—is the perfect amount for any 1080p and 1440p gaming machines. It's also enough for any multitude of programs, enabling you to run Chrome tabs, Discord, and a game all at the same time, without too much trouble. It's also ideal for non-3D Photoshop work, and to get your head into the world of Premiere Pro, too—although After Effects would, of course, benefit from more memory.



MOTHERBOARD

MSI B450M MORTAR

$95

SPENDING HARD CASH ON motherboards when you're on a budget is almost always a challenging thing to convince yourself to do. A lot of the time, to hit that $100 mark, you're left with a sour taste in your mouth, because most mobos look ugly and sparse. There's little in the way of personality at that price.

MSI's B450M Mortar is a fine example of a manufacturer bucking that trend. From the stylized heatsinks to the reinforced PCIe bracket and plethora of connectivity options, it's a nice all-rounder to pair with our case and Ryzen 5 processor. On top of that, MSI has the second-best BIOS UI we've encountered to date, and for $95, that's not to be sniffed at.

MORTAR
CORE BOOST
DDR4 BOOST
msi
B450M MORTAR

SOLID STATE DRIVE

ADATA
Ultimate
Solid State Drive
SU630

480GB ADATA SU630 2.5-INCH SSD

$58

FOR THIS BUILD, we've decided to go with a single solid-state drive to power everything: Adata's SU630 480GB SSD. It represents a huge value proposition right now, as it comes in at just $58. Yeah, you're going to have to be a little sparing with your apps and media, but overall it's hard to pass up the opportunity, even if the performance mostly comes from the SLC cache buried within it.

In an ideal world, we'd recommend you go with something like an 860 Evo 250GB instead, then pull an HDD from an older machine for everything else, if you're on a budget. But if you absolutely must have a sizeable and affordable SSD, the SU630 is the way to go.

POWER SUPPLY

500W COOLER MASTER MASTERWATT LITE

$50

FROM THE WALL, our system should be drawing around 315W when under maximum load. So, this time around, we've gone with a named-brand, non-modular 500W power supply, which gives us around 37 percent headroom for any future upgrades, and plenty of leeway if we want to overclock our Ryzen 5 2600. It's always advisable to stick with a branded PSU, because if it dies, and takes your system with it, you'll need a decent warranty to rely on to recoup your losses—something you won't get with that $30 monstrosity on Amazon.

230V
500
MASTERWATT LITE
COOLER MASTER

COOLER

AMD WRAITH STEALTH $0

NOTHING SAYS VALUE quite like "free," does it? Or rather, "included," because this cooler comes with the Ryzen 5 2600 and is part of the overall cost. AMD's Wraith Stealth is a nicely designed, low-profile air-cooled heatsink for your Ryzen 5 2600, and it packs more than enough thermal performance to help alleviate the heat output of your six-core processor.

You can now buy a few different variants of this from after-market sellers, and for our build, we've gone for the Spire model of the Stealth (because we really wanted that red LED ring, OK?), but generally they all perform exceptionally well straight out of the box, and even come with thermal paste pre-applied.

thermaltake

CASE

THERMALTAKE LEVEL 20 VT MICROATX

$99

LAST BUT NOT LEAST, we've gone for something of an unorthodox chassis for this system. Thermaltake's Level 20 VT reminds us a lot of the BitFenix Prodigy. Its horizontal motherboard mounting system, the massive 200mm front intake fan, and the huge amount of modularity embedded within it make it a prime candidate for our microATX ambitions.

Its looks are certainly open to interpretation, that's for sure, but on the whole, it's not too bad. There's plenty of glass here to enjoy, and although it's a funky case to build in, there are some creature comforts to keep things in check.

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thermaltake

SMASHING THROUGH A THERMALTAKE CHASSIS

LENGTH OF TIME: **1–2 HOURS** LEVEL OF DIFFICULTY: **MEDIUM**

YOU KNOW WE MENTIONED how much management likes slapping a big number on the cover of the magazine? Well, you can see where this build went early on. Originally, it was based on a $799 budget, and although that's certainly possible, it didn't meet that perfect price to performance ratio we wanted to achieve, so after a hell of a lot of tweaking and nagging, we managed to bump that figure up to $999.

Actually, it came to a bit more than that initially, with the final price tag at $1,025, but checking prices just before going to press saw it slip back down to our initial goal. Spot on it in fact. You can probably build for less anyway, especially if you already have some form of Windows license, and if you're upgrading or migrating a system, simply entering the key upon installation, or logging in to your account and authorizing the edition of Windows, will happily authenticate the system, and give you full access to all of those Windows features we love. So, the total hardware cost is just $899.

We could have saved a bit of cash here and there, particularly with the storage (Samsung's 860 Evo SSD is now $70 for a 500GB version), but on the whole, we're pretty happy with how the whole thing turned out. It'll be pretty nifty at 1080p gaming, and our processor of choice, the Ryzen 5 2600, is actually the best value processor we've seen to date.

DECISIONS, DECISIONS

From the outset, we knew we wanted to roll with a Ryzen 5 2600, and either a Vega 56 (surprisingly affordable nowadays) or an RX 590. Reason being that both cards represent a pretty strong value proposition these days, and as we hadn't had a good look at Vega 56 for some time, we thought it might have been worth a second try.

After much debate, we finally settled on the RX 590, because it pulled us below the $999 mark, and still provided us with solid frame rates at 1080p. 16GB of RAM seemed like a sensible decision, too—8GB setups seem to have gone the way of the dodo, and with ever expansive Chrome footprints and a myriad other apps sucking up memory nowadays, having more capacity should make the world of difference. Pairing that capacity with a high frequency should also help keep our Ryzen sample running at full tilt.

The last things we had to consider were the case and the SSD. We would have liked to have featured Fractal Design's Meshify C Compact for this build, but, we just couldn't get it in time, unfortunately, so we chose the Thermaltake Level 20 VT instead. Although visually striking, it is a bit of an anomaly, thanks to its layout. If we were to redo this build, either Fractal's Meshify C Compact or our favorite mATX case from NZXT (the H400i) would be our preferred choice.

1 CHASSIS STRIP-DOWN

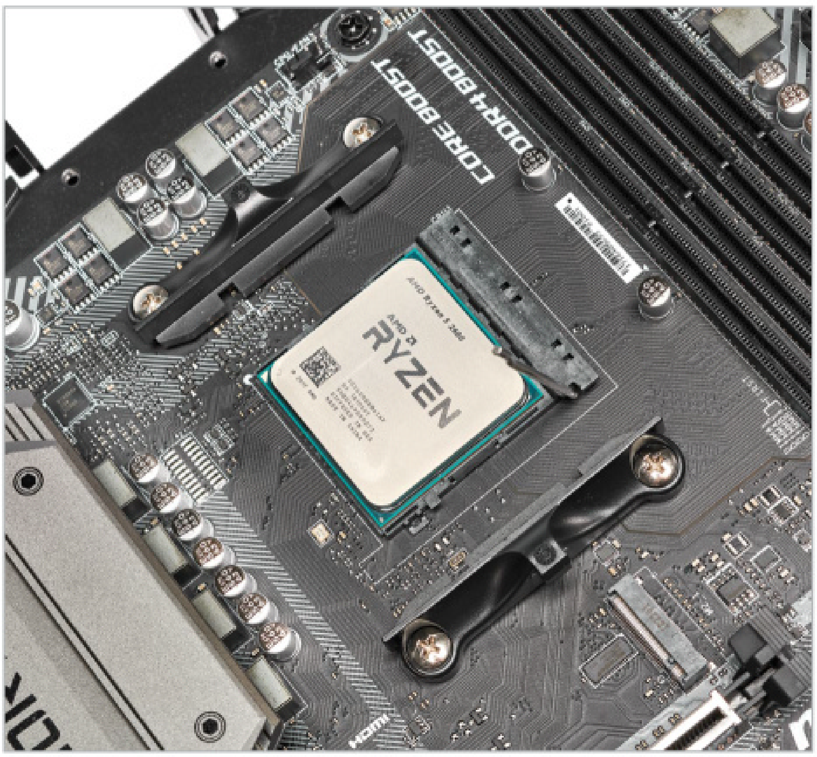
THE FIRST THING WE DO with any case is strip it down as far as possible. That means removing as many panels as we can, along with any internal mounting hardware that we don't need, and making sure the fans are in the right position, too. We've left the front 200mm fan in this build, simply because we have nothing to replace it with. Always keep your tempered glass panels safe, ideally wedged between the sheets of polystyrene in your case box, if possible. It's also handy to have a magnetic bowl or tub around for you to put all your screws in, so you don't lose them. As a final preparation, make sure you're working in a static-free, safe environment (don't worry about a static strap; just earth yourself every now and then on something big and metal), and you're good to go.

2 MOBO INSTALL

BECAUSE OUR BUILD is relatively straightforward, and the cooling isn't exceptionally complex to fit, it's OK to install your motherboard first here. Grab your rear I/O shield and fit that first, pressing it in from the inside, making sure to orient the ports and cutouts correctly. Then slide your motherboard into position, over the motherboard stand-offs, and secure down with the correct screws. If you have a more advanced cooling solution, we advise holding off on this step, unless the CPU cutout is substantial, and first install the mounting hardware for your cooler, before installing the motherboard into the chassis.

3 RYZEN READY

INSTALLING RYZEN PROCESSORS is genuinely one of the least daunting parts of building a PC nowadays. Especially in contrast to Intel's LGA setup, where if you bend even one pin out of alignment, it could mean the death of your mobo. In Ryzen's case, lift the retention arm up, locate the gold triangles on the corners of your processor and the CPU socket, line them up, gently slot the CPU in, then secure the retention arm back down again. Simple.

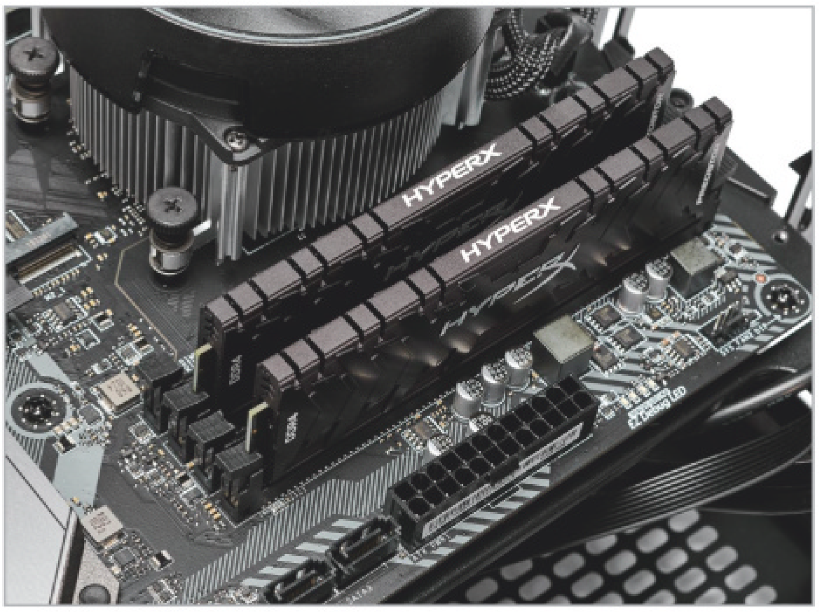


4 COOLER CRAFTSMANSHIP

NOW YOU'RE READY to chill your processor. If you're installing an aftermarket cooler, you should follow the instructions in the manual. With our Wraith Stealth, however, it's a little more straightforward. You need to unscrew both of the mounting brackets AMD includes as standard, to the north and south of the processor. Then, with the backplate still in place (preferably held up by your hand), gently place your new Wraith on top, and secure the screws down, a little bit at a time, in a diagonal or star shape pattern. Screw in the top-left one, then the bottom-right, then top-right, then bottom-left, until it's secure. If it's a second-hand cooler, an aftermarket heatsink, or one you've used before, remember to make sure you place some thermal paste on the processor before you install the cooler. Oh, and don't forget to connect your fan cable to the CPU fan header.

5 MAKING MEMORIES

INSTALLING YOUR DDR4 is a fairly simple process. Make sure you line up the notch on the bottom of each memory stick with the notch on the DIMM slot, lift the retention clips up on each end, then slowly place each stick straight down, until it clicks into place and the clips latch back down. Typically, you have to make sure you use the color-coded slots to ensure you're getting your dual-channel operation; however, some motherboards might prioritize one pair of slots over the others. Check the manual or, in our case with the Mortar, the motherboard itself, because it tells you which two channels it wants you to plug memory into first.



6 BIZARRE POWER INSTALLATIONS

IT TOOK US A WHILE to get to grips with how you actually install this power supply. Most cases allow you to install your PSU either from the rear of the case or the side. With the Level 20, however, this isn't possible. To get your power supply installed, you have to remove the two thumb screws located at the bottom of the floor panel, then lift the entire chassis frame out of its base. Then, with the frame out (and hardware still attached), you can either place the PSU in the bottom plate and drop the frame back down, or secure it to the frame before securing the frame to the base once more. It's a little unintuitive, but not too challenging. Also, remember to make sure your fan is facing downward, because there's nowhere for the power supply to draw air in from directly upward.

7 CABLE MAGIC

NEXT, YOU'RE GOING TO WANT TO start plugging in your cables where you can, and try to sort out that tangled mess. Begin by pre-routing your cables where you want them to go: the 24-pin, the PCIe power pin, and the eight-pin CPU power. Keep an eye on any Molex or SATA devices you want to install, then go ahead and do your best to fold up and secure the rest of the cables with cable ties. This helps keep them out of the way, and improves airflow, too. We've also plugged our front fan into an onboard system fan header, and rerouted our front I/O cables to the other side of the case, to allow better access to the front panel headers on the motherboard.

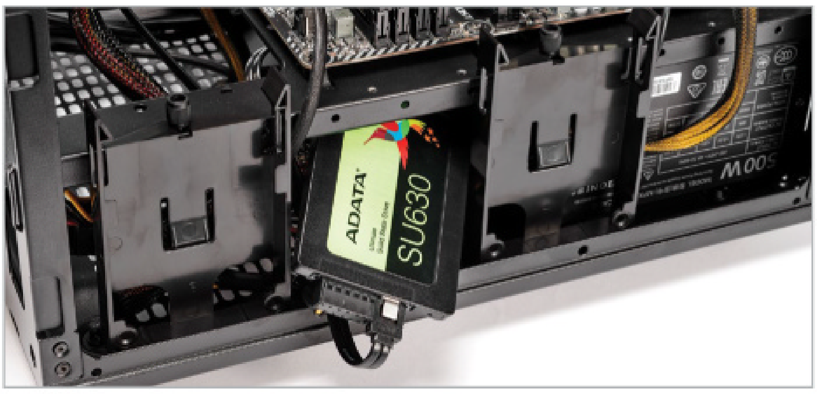
HYPERX
HYPERX
DDR4 BOOST
CORE BOOST

8 GRAPHICAL TOMFOOLERY

NOW IT'S TIME TO GET YOUR GPU IN. To do this, remove the two screws holding down the rear PCIe covers, and lift them out of the case. Then you need to carefully line up your graphics card with the uppermost slot on your motherboard ours is reinforced with steel, and bright silver, (in contrast to the other slot, which is black). Then line up the GPU with the rear I/O and the PCIe slot, and firmly push the GPU into place. Once that's done, you can take that PCIe cable you routed earlier and plug it into the PCIe power at the top. We've actually tucked our cable down into the GPU itself, because the shroud extends further than the PCB of the card.

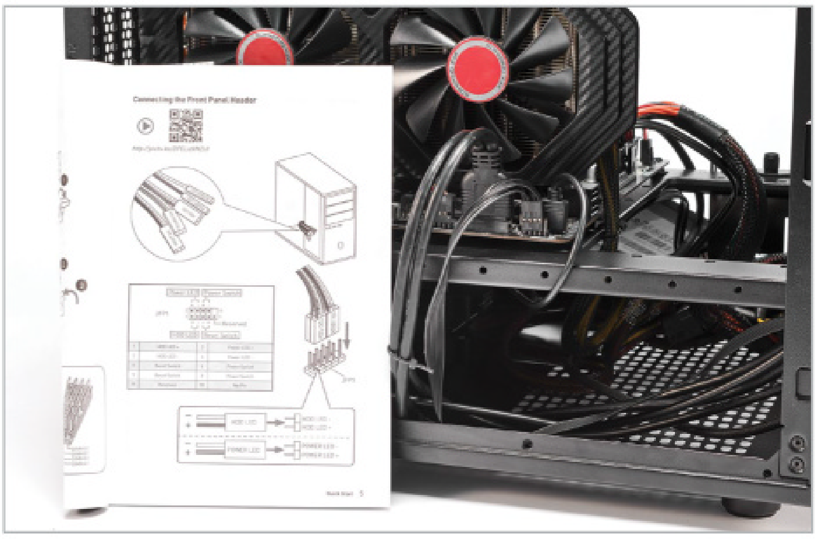
9 SSD MOUNTS?

NOW, YOU MAY BE THINKING: Those look like SSD mounts to the left and right. And the answer should just be: Yep, they are. However, they suck. Seriously suck. The only way you can install an SSD is with the label facing away from you, and even if you decide to do that, you can't have the ports facing down—what you're left with is an SSD in a caddy, with a label facing backward, and the ports on top. Yup. Design oversight, thy name is Thermaltake. We're actually using them as a form of cable management here, trapping the CPU cable down against the PSU, and then keeping the SSD loose in the chassis. Because it's not a spinning disk, our SU630 doesn't mind which way you orient it, so tucking it out the way underneath the motherboard tray is a solid bet. We could have fitted it in one of the 3.5-inch hard drive caddies underneath the GPU, but that would mess with our cable management bundle, and as airflow is only provided by that 200mm fan, the more we have of that, the better.



10 IS THAT A MANUAL?

YES, IT IS. MSI is one of a handful of manufacturers that drive you up the wall when it comes to front panel connectors. Most manufacturers—Gigabyte, Asus, EVGA—include written instructions on the motherboard as to where each pin needs to be installed. MSI doesn't. JFP1 signifies where the front panel headers are, but unless you've got a keen memory, or work with MSI motherboards every day, you're going to have no choice but to dig out the motherboard manual so you can plug each connector into its required slot. Remember, for HDD and power LEDs to operate correctly, the + and – need to be correctly oriented on the pins. We've also installed the USB 3.0 header, USB 2.0 header, and the front panel HD audio connector while doing this bit of the build.



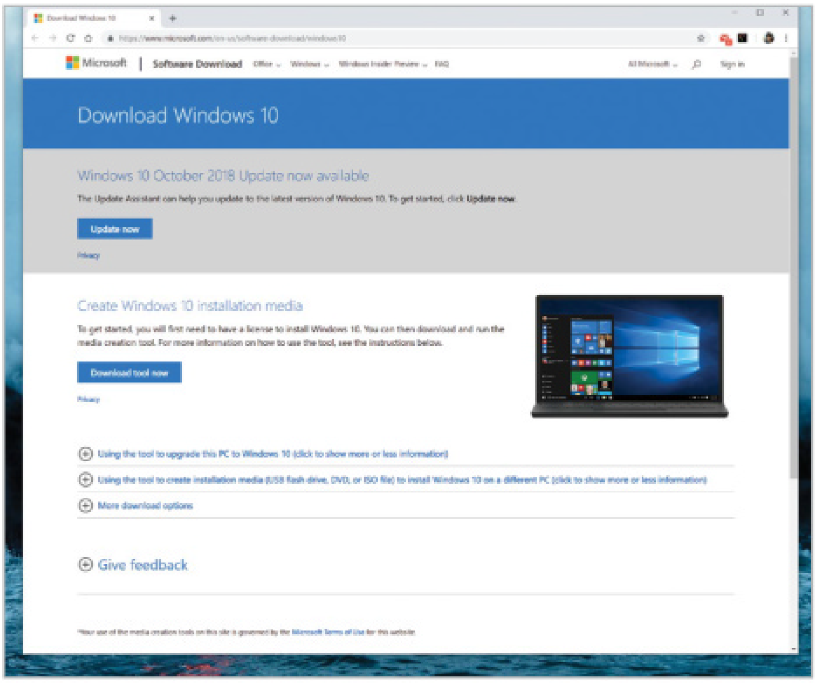
11 PANEL TIME

ONCE THAT'S DONE, it's time to fit all the panels back on the chassis. First, though, plug your system into the wall, power on the PSU, and hit that power button up top. If it boots, you can switch it off again, and begin re-assembling your case. Remember to make sure there are no fingerprints on the underside of each panel as you secure it back down, especially when you're working with tempered glass. The last thing you want is to finish fitting all those shiny new panels, then have to take them off again to get at the smudges. Once you've reached this step, voila—you're done. The building part of this rig is all wrapped up, so now we can move on to software.

thermaltake

12 WINDOWS INSTALL

LAST BUT NOT LEAST, you need to crack out a Windows install USB. To do that, on a separate Windows 10 PC, head to http://bit.ly/Win10MediaKit, click the big "Download tool now" button, then double-click the EXE file that downloads. You need an 8GB USB stick installed beforehand, but this runs you through the USB boot tool creation wizard. Once done, you need to plug the USB stick into your new machine, power it on, then mash the Delete key to get into the BIOS, change the boot order, so your USB is first, hit F10, save, exit, then go through the install process.



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To get started, you will first need to have a license to install Windows 10. You can then download and run the media creation tool. For more information on how to use the tool, see the instructions below.

Using the tool to upgrade this PC to Windows 10 (click to show more or less information)

Using the tool to create installation media (USB flash drive, DVD, or ISO file) to install Windows 10 on a different PC (click to show more or less information)

More download options

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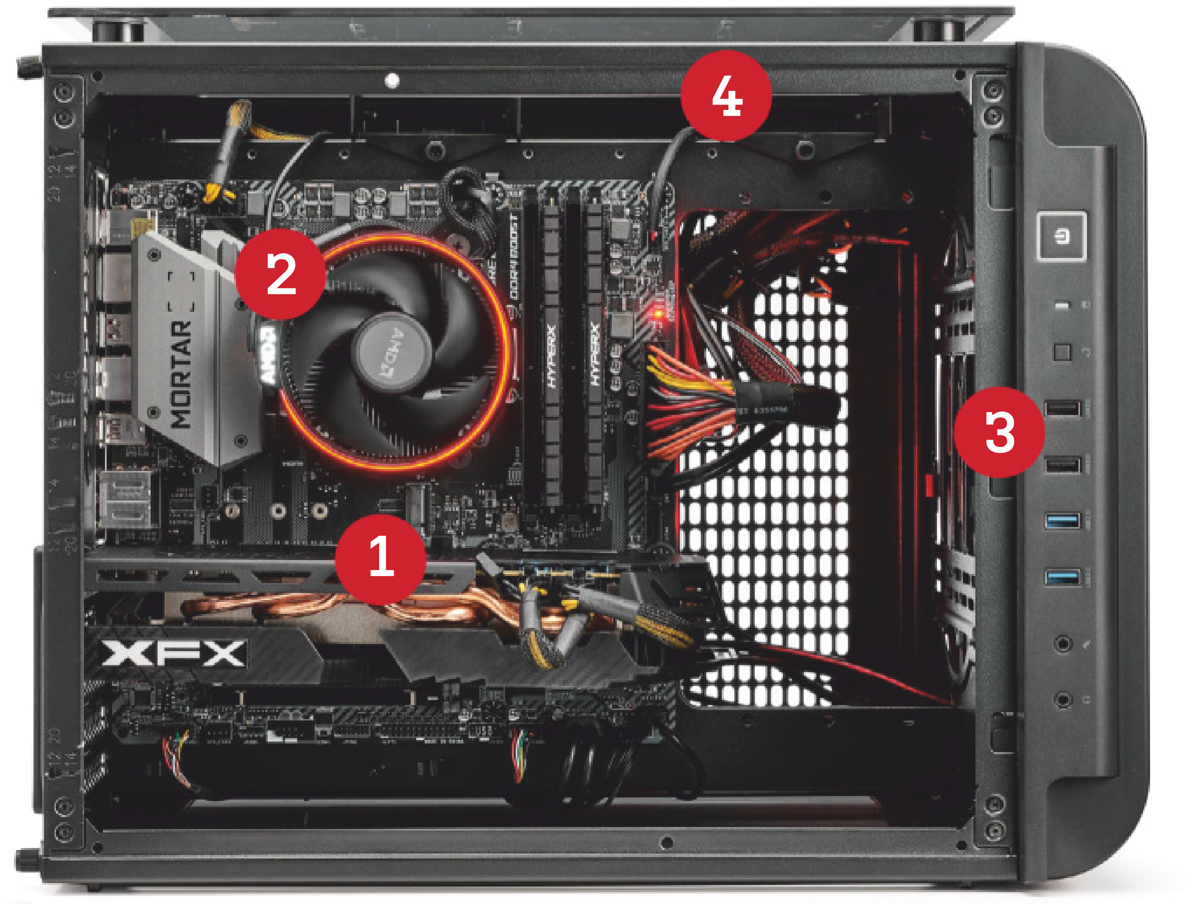


1 **A top-down look this time around, but you can see why this style of design often leads to a mess when it comes to interior cable management. It's difficult to route things when the mobo is flat.**

2 **We've gone with AMD's Wraith Spire on our build, because we wanted to add a little pizzazz to the affair.**

3 **We've removed the radiator brackets at the top of the chassis to help us maintain a clean top-down aesthetic.**

4 **A good upgrade for this would be to drop in a 250GB Samsung 960 Evo M.2 drive here, for some OS grunt.**

CASE STUDY

OUR $999 BUILD is complete, and what a journey it's been. The Thermaltake Level 20 VT was not the chassis we wanted to use—it's interesting, don't get us wrong, but it's not what we'd call a conventional case to work in. Alas, print deadlines stop for no man, and we had little choice but to forsake our delayed Fractal case and instead opt for the glass confines of this giant cube.

Was it a challenge? Yes and no. Less challenging, more confusing. Once all the glass panes were removed, the first issue was the roof bars in the top. These aren't screwed down; rather, there's a thin slice of metal securing each bar in place that you have to bend up to get the bar out. Then there was the power supply installation. There's no obvious or easy way to install a PSU into this chassis. You can't do it sideways, you can't do it from the rear. As mentioned, we had to unsecure the base, lift up the remainder of the chassis, then drop the PSU into place, before carefully repositioning the chassis back down, and securing it and the power supply. It's a clumsy solution, but it works.

Then there's the SSD caddies. What a nightmare. Only one set of mounting screw locations, which forces your label the other way around, and no way to make the connectors face the bottom. We'd also have liked to see an easier way of mounting those traditional 3.5-inch hard drives, preferably from the rear, in a more hot-swappable manner. The notion of hot-swap hard drives may be pushing up daisies right now, but reaching around inside to pull the sleds out feels unintuitive.

Other than those pesky case chassis conundrums, though, the overall spec of this rig—16GB of RAM, an RX 590, a fairly sizable HDD, and a six-core, 12-thread processor—is incredibly sound and gives it some serious grunt for any task you throw its way.

That 16GB of DDR4 @ 3,200, paired with our Ryzen 5 2600, makes it a true pro at any and all multithreaded tasks you throw its way, and as more games are leaning toward a "more threads the better" standpoint, it won't let you down in the future there, either. The RX 590 is also an incredibly cost-effective card for 1080p. Yeah, we weren't happy with it at launch, but that doesn't stop it from being a solid card at this resolution, beating even the GTX 1060 when it comes to value per dollar.

The weakness of this rig lies with the SSD, however. Unfortunately, Adata's QLC-based SU630 is incredibly underwhelming. From the lackluster cache to the poor long-term sequential performance, coupled with some serious doubts about endurance, it simply doesn't make sense as a drive. The fact that you can now pick up a 500GB Samsung 860 Evo for only a bit more cash means that there's just not enough to convince us of QLC's value right now.

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi-Thread	1,152	1,242 (8%)
CrystalDisk QD32 Sequential Read (MB/s)	3,400	558 (-84%)
CrystalDisk QD32 Sequential Write (MB/s)	1,720	521 (-70%)
Rise of the Tomb Raider (fps)	60	70 (17%)
Total War: Warhammer II (fps)	46	47 (2%)
Tom Clancy's Ghost Recon Wildlands (fps)	39	42 (8%)
3DMark: Fire Strike (Index)	11,101	13,441 (21%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our zero-point consists of an AMD Ryzen 5 1600, 16GB of Crucial Ballistix Sport LT @ 2,666, an EVGA GeForce GTX 1060 3GB, and a 250GB Samsung 960 Evo M.2 PCIe SSD. All tests were performed at 1080p at the highest graphical profile.

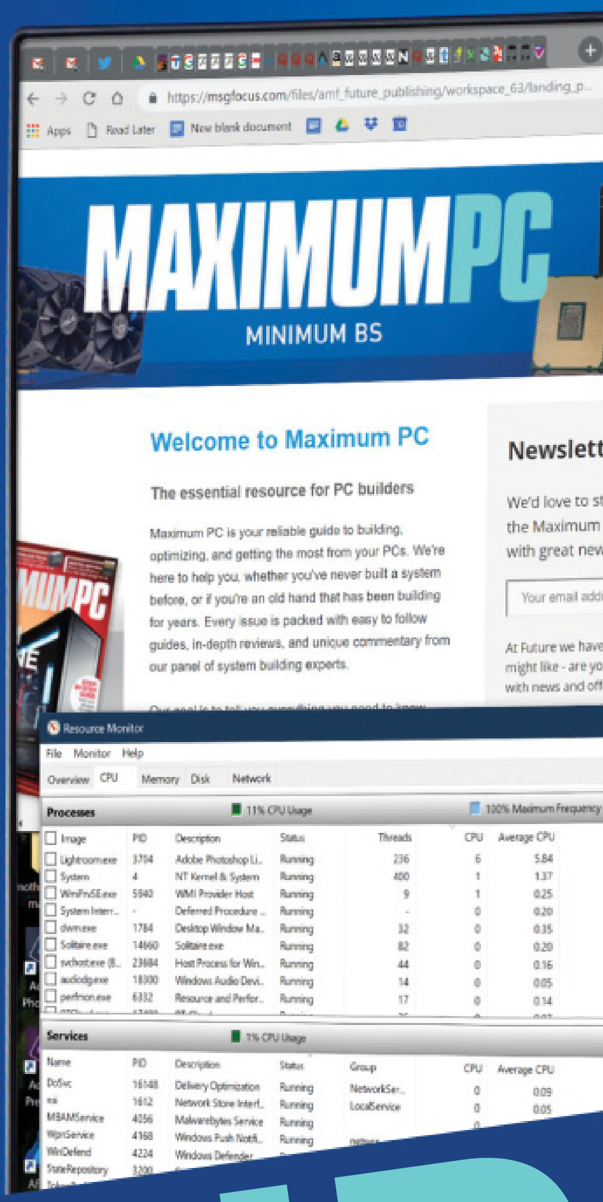
MULTITHR MONSTER

It's easy to build a multicore PC, but what can it do?

Multicore CPUs are so commonplace, you'd be hard-pressed to build a PC today that isn't packed with cores. You certainly wouldn't want to, as the performance benefits of additional processing cores are noticeable, and keep today's PCs on the cutting edge. The Pentium Dual Core brand dates back to 2006's Yonah core, while AMD was producing Athlon 64 X2s with Hammer cores in 2005. That's not to mention the work outside the X86 space, with ARM and the graphics card manufacturers also using multiple cores.

Recently, however, there's been a core explosion. Quad-core held the top spot, at least outside of servers, for a long time, as Intel worked through several iterations of Core chips, but the resurgence of AMD with its Zen and Zen+ architecture means you can now buy a six-core Ryzen 5 2600 for $200. Simultaneous multithreading (the ability for each core to work on two software threads at the same time, known over at Intel as Hyper-Threading, and used since the Pentium 4) means this chip can process 12 threads simultaneously. Intel will sell you an 18-core, 36-thread chip, while AMD's line goes all the way to 32 cores and 64 threads. There's never been a better time to chew through large amounts of data on your desktop.

These are processors aimed at home PCs, not destined for supercomputers (which have moved over to GPUs with tens of thousands of cores for their specialized workloads), so the datasets they deal with are more mundane. GPU-based supercomputers are starting to run the world, from universities carrying out scientific research to Amazon Web Services and the tech behind the Google Assistant and Siri, offloading tasks such as AI and speech recognition to what's euphemistically called "the cloud." That doesn't mean you can't have a little fun at home, however. From the future of gaming to creative endeavors to making new scientific discoveries, there are many more uses for your new multicore monster than just manipulating gigantic databases.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The essential resource for PC builders

Maximum PC is your reliable guide to building, optimizing, and getting the most from your PCs. We're here to help you, whether you've never built a system before, or if you're an old hand that has been building for years. Every issue is packed with easy to follow guides, in-depth reviews, and unique commentary from our panel of system building experts.

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We'd love to st
the Maximum
with great new

Your email add

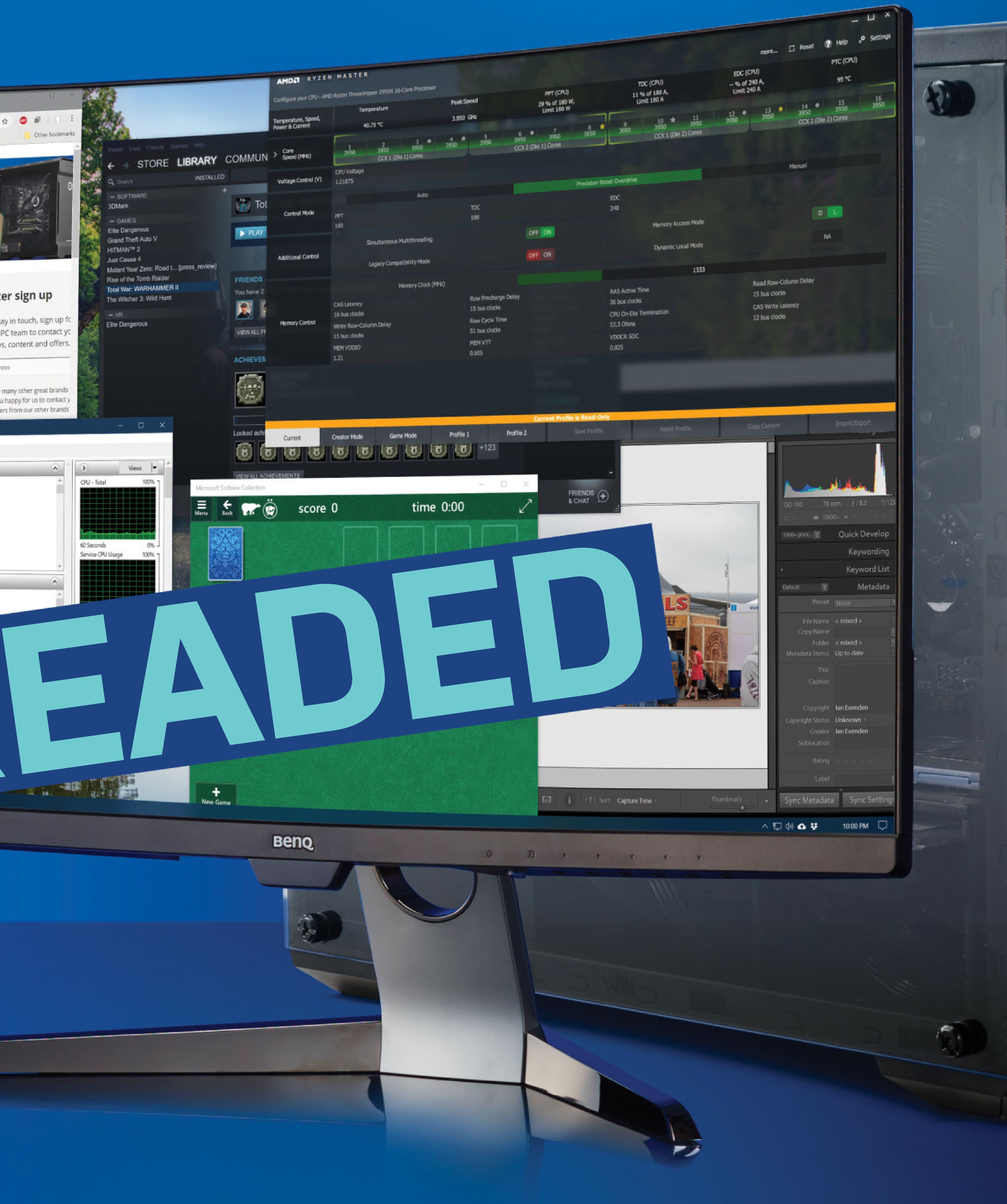
At Future we have
might like - are yo
with news and off

Processes — 11% CPU Usage — 100% Maximum Frequency

Image	PID	Description	Status	Threads	CPU	Average CPU
Lightroom.exe	3704	Adobe Photoshop Li...	Running	236	6	5.84
System	4	NT Kernel & System	Running	400	1	1.37
WmiPrvSE.exe	5940	WMI Provider Host	Running	9	1	0.25
System Interr...	-	Deferred Procedure ...	Running	-	0	0.20
dwm.exe	1784	Desktop Window Ma...	Running	32	0	0.35
Solitaire.exe	14660	Solitaire.exe	Running	82	0	0.20
svchost.exe (...	23684	Host Process for Win...	Running	44	0	0.16
audiodg.exe	18300	Windows Audio Devi...	Running	14	0	0.05
perfmon.exe	6332	Resource and Perfor...	Running	17	0	0.14

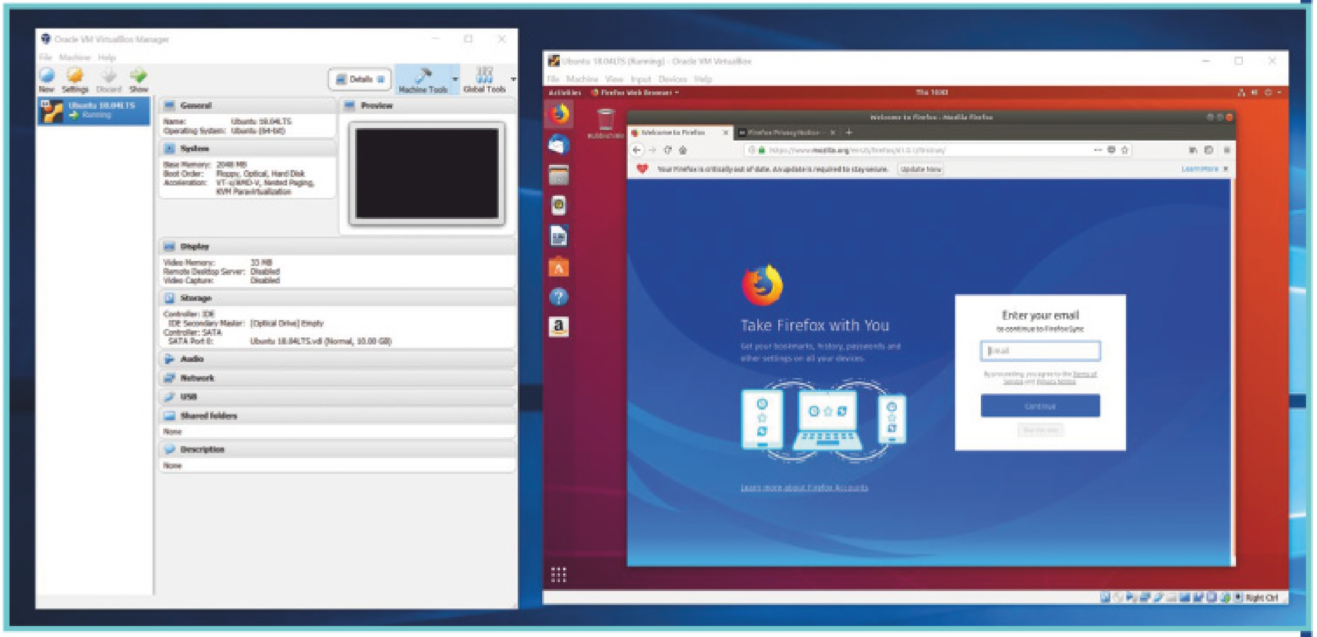
Services — 1% CPU Usage

Name	PID	Description	Status	Group	CPU	Average CPU
DoSvc	16148	Delivery Optimization	Running	NetworkSer...	0	0.09
nsi	1612	Network Store Interf...	Running	LocalService	0	0.05
MBAMService	4056	Malwarebytes Service	Running			
WpnService	4168	Windows Push Notifi...	Running			
WinDefend	4224	Windows Defender				
StateRepository	3200					


AMD RYZEN MASTER
Configure your CPU - AMD Ryzen Threadripper 2950X 16-Core Processor
Precision Boost Overdrive
Current Profile is Read-Only
STORE LIBRARY COMMUN
Microsoft Solitaire Collection
score 0
time 0:00
New Game
Quick Develop
Keyword List
Metadata
Sync Metadata
BenQ

EADED

VIRTUAL MACHINES



Linux running on top of Windows, but this isn't an emulator.

You can run lots of apps, so how about lots of operating systems? Virtual machines enable you to run "guest" operating systems on top of the "host"—the OS that runs when you start your PC up. The guests can be extra copies of Windows 10, unstable preview builds, Linux, Chrome OS, or anything else you can think of that will run on an X86 chip.

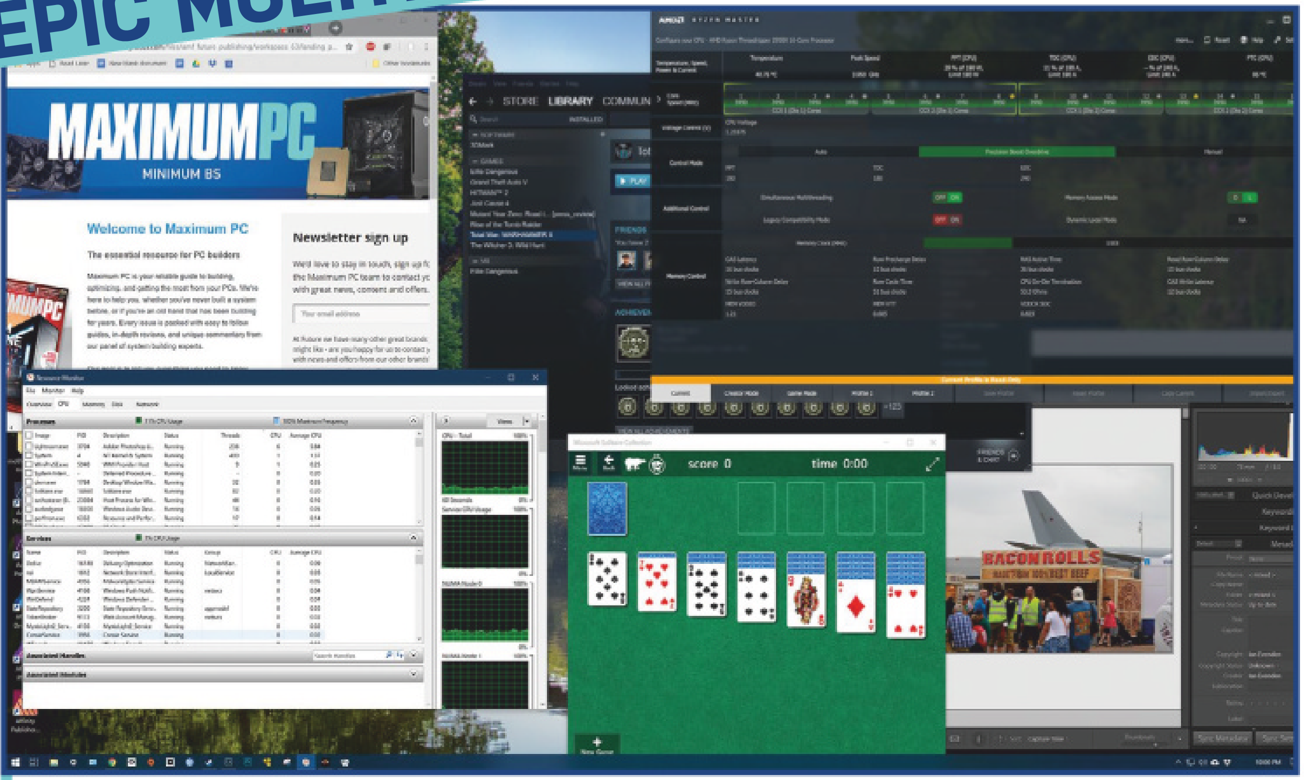
The hardware side of virtualization goes by many names (VT-x for Intel, AMD-V for AMD), and while it's possible to do it on all modern CPUs, the ability to do so may be switched off by default—you need to enable it in the BIOS. When you set up a virtual machine, you specify how many processor cores and how much RAM it can access, and these are then hived off and dedicated to the guest.

This means you can run a VM very well on a quad-core chip, as long as you don't mind offering it only two cores and dealing with a slowdown of your host PC as well. With 16 cores, you can run two VMs with four cores each, and still retain eight to run your host—more than enough.

VMs are useful for testing—we use them to try new features in Insider Preview builds of Win 10 without installing these possibly unstable builds on our host PC *[actually, some of us like living on the edge, and run the Insider Preview on our main PC—Ed]*. You can also try Linux without going to the trouble of setting up dual-boot, and if you've got a legacy application that only likes to run on Win 7, for example, you can keep it in a VM. Because VMs are isolated from their hosts, a misbehaving app can bring down the VM without affecting what you're doing elsewhere.

Mobile app developers can use virtualized phones to run their creations on, and creating software builds can be a multithreaded process, while web developers can run a virtual web server for testing. These are all useful things in a production environment, particularly for freelancers working from home.

EPIC MULTITASKING



With enough cores, you can open as many apps as your RAM can handle.

Back it with enough RAM, and your multicore processor can significantly increase the number of applications you can get useful work out of at the same time. The rule of 2GB per core has held well for several years, but is starting to break down as apps, especially games, demand more RAM.

Multitasking is a great way to exploit a multicore processor, as it sidesteps the need for your apps to be written with multithreading in mind. Each app will have its own threads, which can be doled out by the CPU's scheduler and spread across the cores.

So, if you want to run an image-editing app while streaming 4K video, and decompressing a huge zip file, you can, but how many of us really work that way? What's more likely is setting an enormous background

Games, Games, Games

Games aren't noted for embracing the multicore world. Intel chips, with their stronger single-core performance, are still the CPUs of choice for gaming PCs, but that doesn't mean AMD's offerings, which are stronger in multithreaded applications, are being left behind. Gamers are more likely to be GPU-limited than waiting on their CPUs right now.

Battlefield V appears to spread itself across a lot of threads, but never utilizes our 16-core Threadripper above 25 percent, which the math tells us equates to 100 percent usage on a quad-core. It's nothing a Ryzen 5 couldn't provide. *Total War: Warhammer II* makes better use of the same system, but tops out at around 50 percent usage. A Ryzen 7 could handle that.

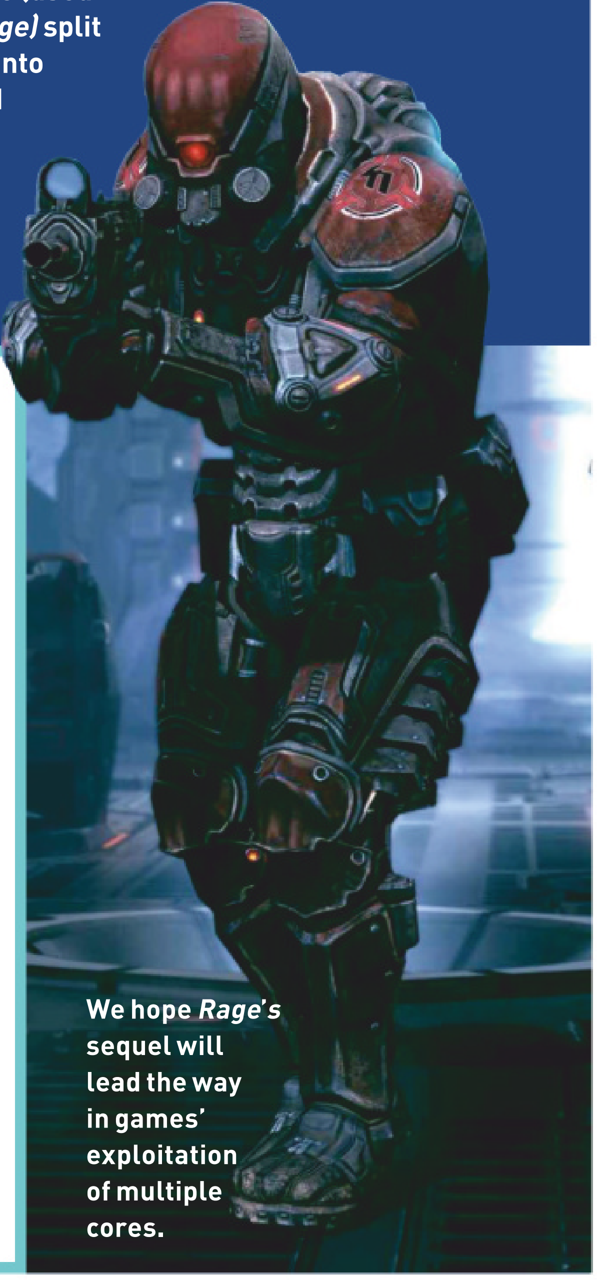
As compute-heavy tasks such as AI are shifted to GPUs, there will be less for the CPU to do. However, as games become more complex and realistic, the tasks left to the CPU require more power. Oculus VR's CTO, and former id Software chief, John Carmack opined back in 2005 that single-threaded applications had had their day, but there would be diminishing returns from the first generations of multithreaded games, as developers figured out how to use parallel processors.

By 2008, he was starting to make progress, explaining at an Intel keynote that the id Tech 5 engine (used for the first *Rage*) split its game logic into one thread and its rendering system into another, with a third to manage streaming, compression, and analysis. *Rage* was a beautiful game, but a very static world, lacking many of the physics interactions we now take for granted.

Ten years on, he seems to have cracked it, stating in a video made in association with AMD that the upcoming id Tech 7 engine, which will power next year's *Doom Eternal*, will "consume all the CPU Ryzen can offer." That's Ryzen, not Threadripper, but the new, more parallel, game engine, along with the Vulkan graphics API that accelerated *Doom*, should show some exciting performance when we get to see it.

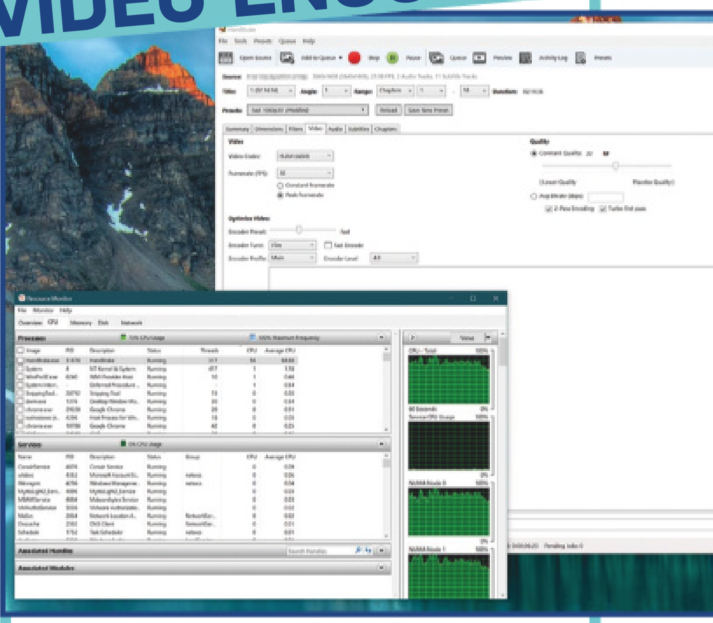
task going, something like generating thousands of smart previews in Adobe Photoshop Lightroom, then opening another app to get something done, rather than looking at progress bars while that big task is completing.

In 2016, Intel decided the word "multitasking" wasn't good enough for what its Broadwell-E decacore CPUs could do, so invented the word "megatasking" to describe their app-switching abilities. Call it what you want, this is one of those things, like opening every app in your Start menu and seeing how long it takes, that you can do to show off, and high-end desktop processors make showing off easy. How useful it is in the real world, however, is another question, as people tend to focus on one thing at a time.



We hope *Rage*'s sequel will lead the way in games' exploitation of multiple cores.

VIDEO ENCODING



Taking video that's been shot in one format, and changing it to another, so it can be displayed or archived more easily, is a classic CPU-intensive task. Exporting your projects from video-editing software will also benefit here.

We took a 4K video file in HEVC (also known as X265), captured on an iPhone, and converted it to the 1080p X264 format our set-top box can manage using Handbrake, a freely available conversion application. A 16-core Threadripper managed the downsampling and codec conversion at an average of 45fps, taking about 70 percent of CPU time, and spreading over more than 300 threads, when all's said and done.

One of the good things we've noticed about Threadripper is that it never gets very hot, even with a modest overclock. We've only got a single 120mm radiator on ours, albeit cooled by two fans, but during our Handbrake tests, it never got above around 55 C. This is possibly due to AMD's use of solder, rather than thermal paste under the chip's lid, or it could be thanks to something deeper within the chip's design.

Another similar task that can be accelerated by an HEDT processor is file compression, with 7zip in particular having a nice, easy-to-find "Number of CPU Threads" option on its "Add to Archive" screen. The LZMA2 algorithm is the one to choose, because it opens up as many threads as you can give it—others are limited to one or two. In our testing, it quickly shot to 84 percent of CPU usage, before backing off slightly to the high 70s.

China's Tianhe-2 is now the fourth fastest supercomputer in the world.

The GPU That Never Was

Intel's canceled project to create a GPGPU chip—a GPU that could be used for CPU-like tasks—is interesting, because it foreshadowed today's multicore world.

Back in 2008, when Intel was pushing Core 2 Duo as its mainstream desktop solution, the company announced it was going to make a graphics card that was a little bit different. It was based on the original Pentium, and eschewed modern trappings such as out-of-order execution and multiple instructions per clock. What it could do, however, was squeeze 10 of its cores into a space no bigger than the Core 2 Duo's two cores.

Graphics cards are built from streaming processors, and Intel's Larrabee lagged behind the core counts of other GPUs of the time, but it had one distinct advantage: While Nvidia's cores could only work on one operation at once, and AMD's could manage five, Intel's could manage 16 operations. This meant it needed a lot of help from the CPU to maximize the utilization of its resources, but Intel had this covered in its CPU designs. The other thing that set Larrabee apart was its programmability—it was completely programmable, using the X86 architecture programmers were already familiar with, while the more dedicated GPUs were only partly programmable at best.

Unfortunately, Larrabee, as initially envisaged, never appeared. Development of the chips fell behind schedule, and the competitiveness of the GPU market left it behind, so Intel canned it. It lived on, however, as Xeon Phi, a series of co-processor boards developed for supercomputing, with up to 72 cores running at up to 1.7GHz. The Tianhe-2 supercomputer in Guangzhou, China, is made up of 16,000 nodes, each of which comprises two Ivy Bridge Xeon CPUs and three Xeon Phi co-processors, for a total of 3,120,000 cores. Each node has 88GB of RAM. The Tianhe-2 was the fastest computer in the world from June 2013 to June 2016.

Intel will ship Xeon Phi chips until July 2019, but after that they're gone forever. Interestingly, Tom Forsyth, the chief architect of Larrabee, is back at Intel as part of the team headed by former AMD graphics boss Raja Koduri, thought to be preparing Intel's entry into the discrete GPU space.

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DISTRIBUTED COMPUTING

Similar to mining pools, but with a less capitalist outlook, distributed computing projects harness the unused processing power of your rig to do good, whether it's by folding proteins, calculating amicable numbers, tracking asteroids, or even detecting planets around distant stars.

A good place to start is Boinc, a project from The University of California, Berkeley, which rounds up science projects from colleges across the world and allows you to contribute to them all. Download the app and you can pick and choose your projects, but join the Science United program and you can direct your processor cycles toward wider areas of research, with the specific projects receiving your help managed by the software. Projects range from pure mathematics to astrophysics and climate change studies, and you get a weekly email designed to make you feel good about your contribution, but otherwise the app may not bother you again.

If medicine is more your thing, you may remember Folding@Home from a million screensavers at the beginning of this decade. The app never went away, and has supported multicore processors since version 7.0. Version 7.5 is free, and can even use GPUs through Open CL.

Proteins are sequences of amino acids that begin life in an unstable random coil state and "fold" themselves into a native 3D state, in which they can take on roles such as molecular transportation, cellular regulation, and as antibodies within our bodies. By simulating their folding, we can gain insight into their workings and potentially produce therapies for diseases such as Alzheimer's or cystic fibrosis. There's even a *Maximum PC* Folding@Home team, with almost 550 active CPUs in it. More complex, but with a much larger reach, is AstroNet, a Google and NASA project that used to be called TensorFlow. Owners of RTX hardware will recognize that word—the Tensor cores in the latest Nvidia cards are designed to accelerate AI and neural nets, which is precisely what this is.

AstroNet sifts through data from the Kepler space telescope, the recently retired planet-hunter that imaged over 530,000 stars in the hope of detecting the tell-tale dip in light as a planet orbiting that star passed across its face. Kepler only searched an area of space around 3,000 light years across, but it still managed to find 2,662 planets.

That number is still rising, as citizen scientists bring their home computers to bear. You can find AstroNet on GitHub, but beware—if you want to download the complete Kepler data, there are three million files that take up a terabyte.

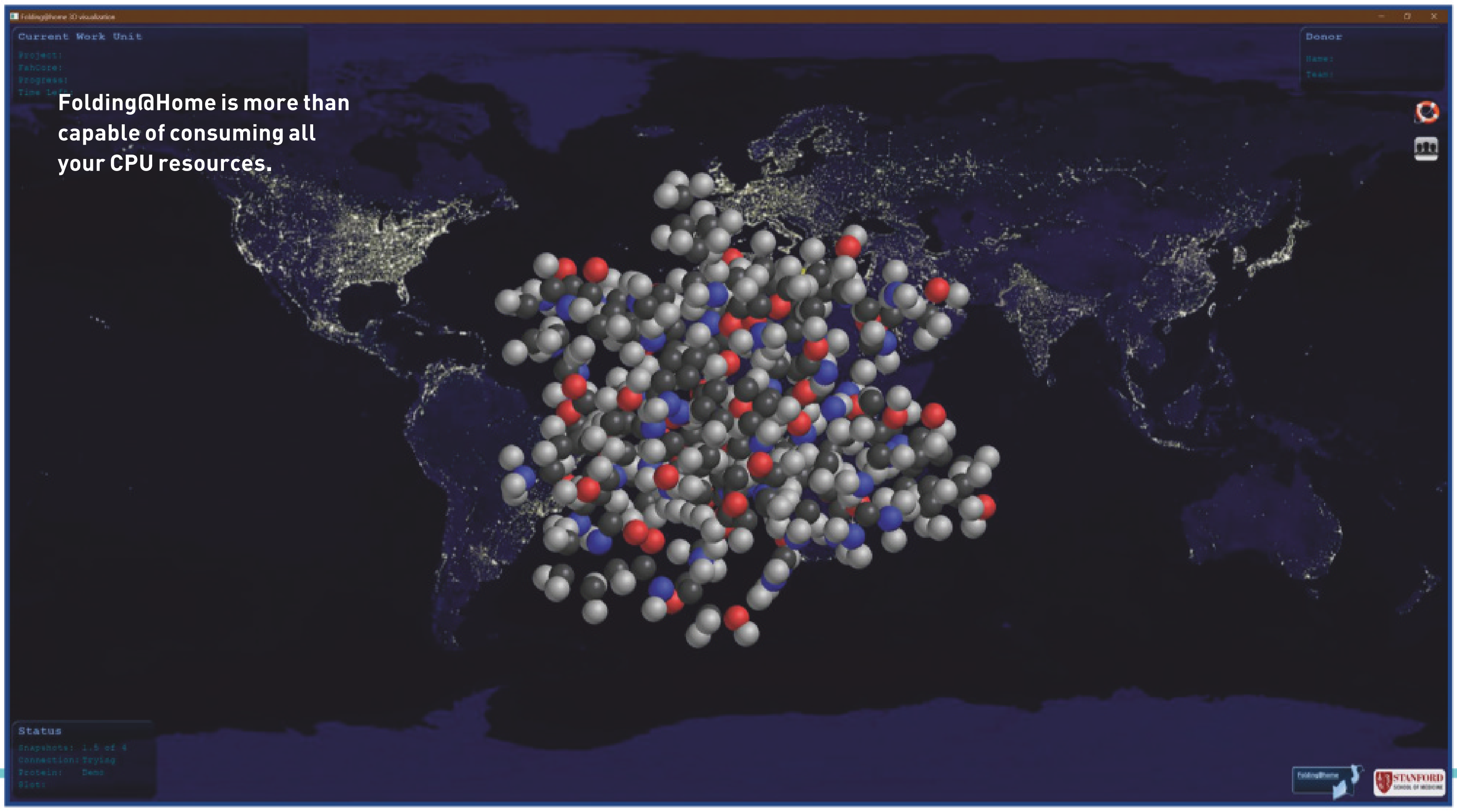
Playing to an Audience

Game streaming, where you broadcast your gameplay to an audience of fans who may give you money, is an expensive business. You need a gaming PC, to play the games on, and you need a fast and reliable Internet connection, a camera and microphone—because the face and voice of the streamer are as important as what he or she is doing—and some way of capturing the video output of your PC and sending it out to your audience.

Some streamers use two PCs, an elegant solution that doubles your costs and power usage. Far better to run the streaming software on the resources of your HEDT PC that are unused by gaming.

Open Broadcasting Software, one of the most popular solutions, automatically utilizes all available threads. Essentially, it's doing background video encoding, taking the output from your GPU and compressing it into something that can be sent over the net. You're given a choice of encoders when you set up your stream, and the "X264" option runs solely on your CPU (there's also a clever "Quick Sync" option, which for Intel CPUs makes use of the probably unused integrated graphics, but the HEDT variants don't have them, so it's not something to discuss here). If you've got enough spare cores, you can use the "X264" option to do the encoding with no penalty to your game frame rates. You can even reserve cores to do nothing but encode video through the "Set Core Affinity" option in Task Manager.

The best streamers need the best computers, not just for frame rates, but for bragging rights, too.



Project:
FahCore:
Progress:
Time left:

Name:
Team:

Status
Snapshots: 1.5 of 4
Connection: Trying
Protein: Demo
Slot:

Folding@Home is more than capable of consuming all your CPU resources.

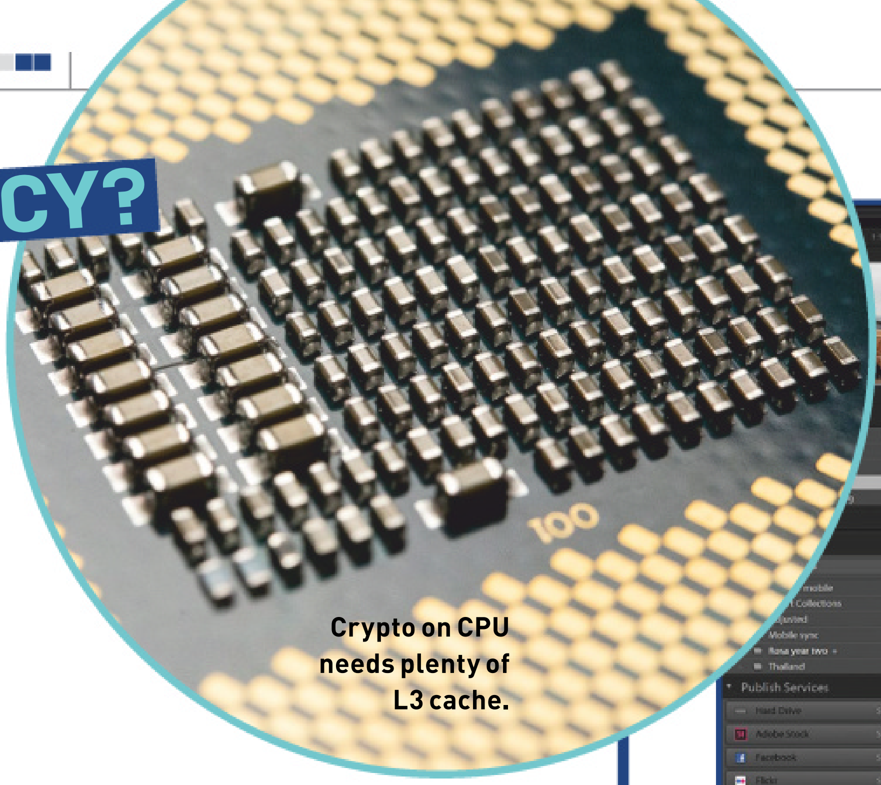
CRYPTOCURRENCY?

Cryptomining is all about racks of GPUs in server cabinets, putting out enough heat to keep your home warm, or dedicated ASIC (application specific integrated circuits) machines with a single purpose—solving the complex math that makes the blockchain tick—and low power requirements. Cryptomining was once something anyone could do, but those days seem long behind us.

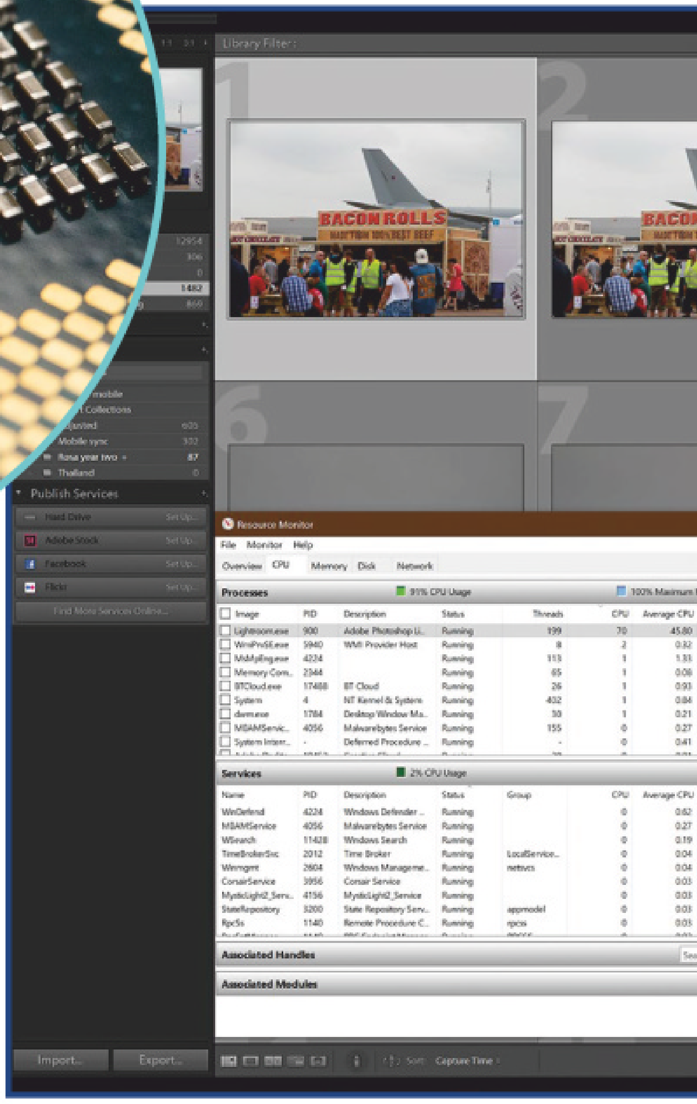
That's certainly true of many algorithms—Bitcoin mining has become so dominated by professionals that only two ASIC setups remain profitable, bringing in less than a dollar a day—but there are some currencies, such as Monero, that have different requirements, and can be mined on a CPU.

The key here is the CryptoNight proof-of-work algorithm, which requires 2MB of memory per instance to run—about the same as the L3 cache per core on a modern HEDT processor. This is more memory than ASICs generally have, and the L3 cache beats GPU memory for speed.

Last year, the NiceHash mining pool was the victim of a hack that saw $60 million in cryptocurrency spirited away, so the process is not without its risks, but if you can meet the energy requirements, CPU mining is a good way for your new HEDT chip to start paying for itself.



Crypto on CPU needs plenty of L3 cache.



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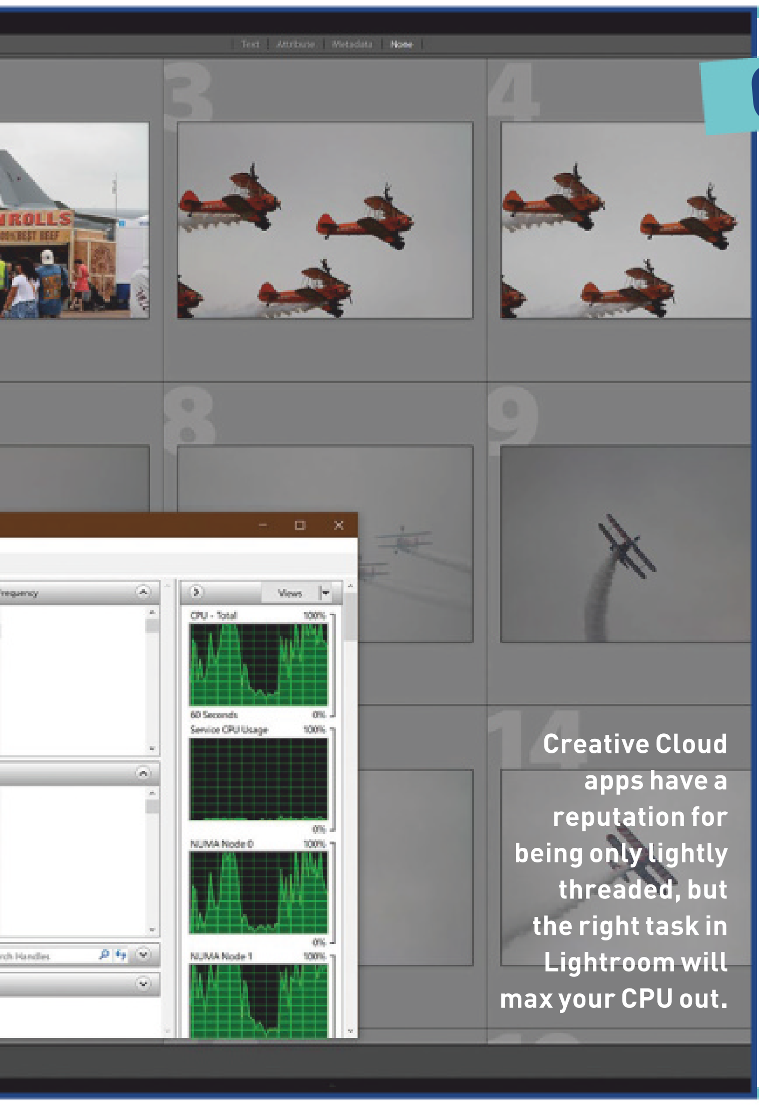

Creative Cloud apps have a reputation for being only lightly threaded, but the right task in Lightroom will max your CPU out.

CREATIVE WORKS

Creative enterprises, such as making fine magazines, often require a lot of multitasking. The designers and art editors who work on *Maximum PC*, for example, use image-editing, vector-design, and page-layout tools they switch between without a thought.

Just flicking through apps is more a test of your RAM than your processing ability, though; it's setting them to an intensive task and still being able to work in another app that counts. Adobe's Creative Cloud apps can suck up a lot of hardware resources, with Photoshop using GPUs to accelerate its effects, but the apps come up short when it comes to multithreading on the CPU. We set Lightroom the intensive task of creating smart previews of almost 1,500 raw images imported from an external hard drive, and watched the CPU usage rise and fall, from 100 percent to as little as 20 percent.

Outside Adobe, the natural media painting app Corel Painter is noted for its multithread awareness, but the real devourers of system resources are video editing and 3D rendering. Premiere Pro, part of the Creative Cloud suite, is definitely capable of taking advantage of your additional cores, but the amount of multithreading it does seems to depend on the task. If you do a lot of warp stabilizing, for example, you might be better off with a low-core-count, but screamingly fast, processor.

Many 3D packages can take advantage of your GPU to accelerate their work, but the CPU is still an important factor. For instance, in Blender, an open-source 3D-creation app you can find on Steam, rendering of your final project is a multithreaded process, but the rest of the app isn't. This goes to underline that while enormous numbers of cores are useful for some tasks, and extremely nice to have for bragging rights, strong single-core performance is still needed to get the most out of today's software.

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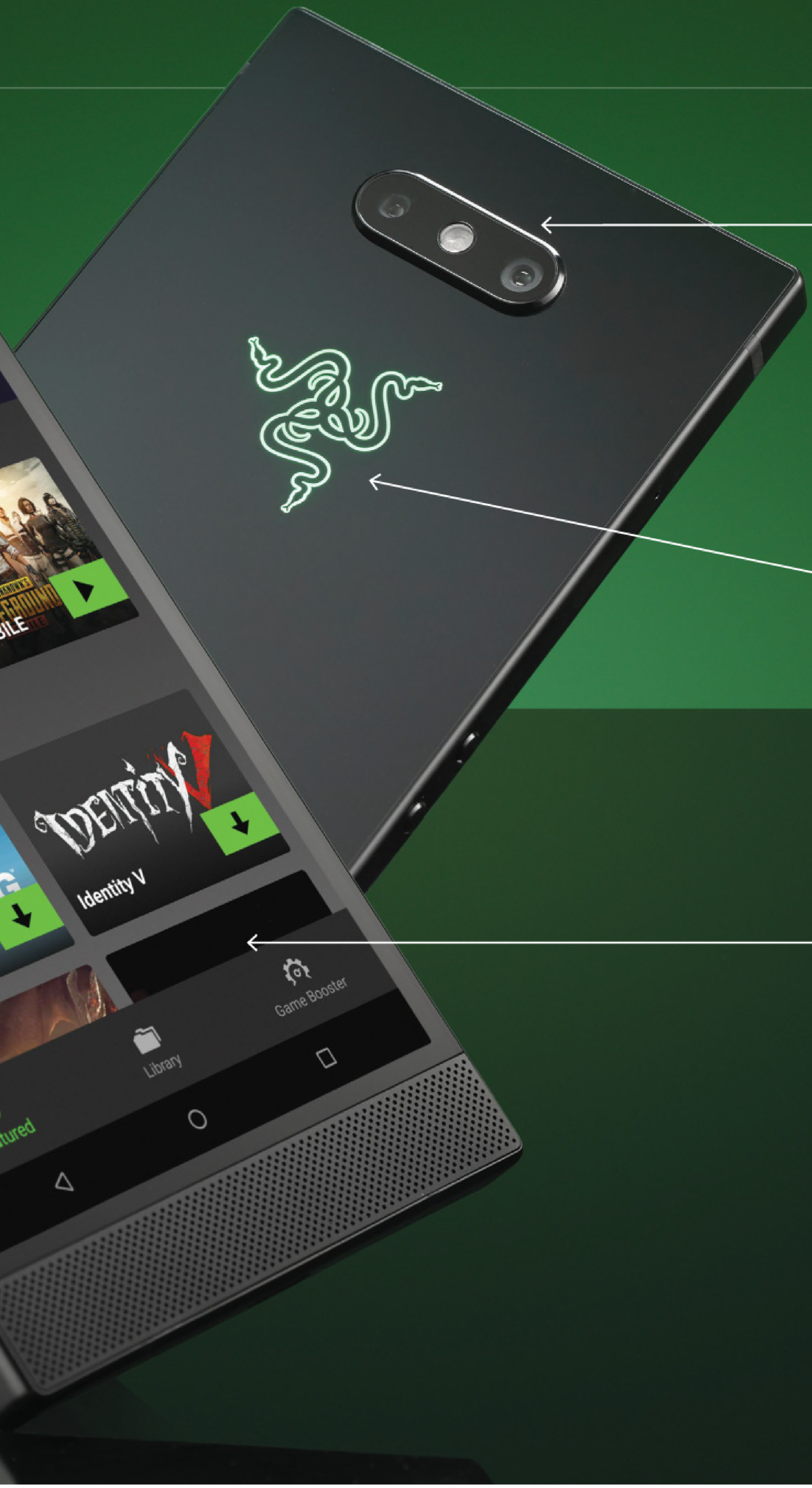
Razer Phone 2

AS WITH THE ORIGINAL, the killer feature of the Razer Phone 2 is its gorgeously smooth 120Hz display. Just like desktop displays, once you've used a high-refresh screen, it's difficult to go back to normal displays, and because this 5.72-inch IGZO 1440x2560 LCD display is 50 percent brighter than the first model, it's even more impressive to use. The front-facing speakers, boasting Dolby Atmos technology, combine with this beautiful display to make for a great gaming and movie playback experience as well—it's easily the best gaming cell we've used.

The reason for its gaming prowess is partly due to the core specifications pulling no punches, with a 2.8GHz Qualcomm Snapdragon 845 providing the raw grunt, and an Adreno 630 GPU powering the visuals. You get 8GB of LPDDR4X RAM to play with, and a healthy 64GB of internal storage for your games and apps, expandable with the microSD slot up to 1TB. This is a premium smartphone, make no mistake, and at $699, it's great value, too.

The Razer Phone 2 charges using USB Type-C, although it also supports wireless charging using Razer's own cradle (not included). It isn't officially compatible with most Qi chargers, because the charging coil is lower than the specification dictates, but you should be able to get it to charge with a little fiddling. **–ALAN DEXTER**



1 DIGITAL IMAGING

Razer has updated the cameras on the Phone 2 to use Sony IMX 12MP sensors, with a wide lens and optical image stabilization (f/1.75), and a telephoto f/2.6 lens for long-distance work. The front camera remains largely unchanged, and is capable of capturing at FHD.

2 REVERSE INDICATOR

The glowing logo on the back of the Razer Phone 2 isn't just for show—it lets you know if you have any notifications waiting for you. You can set the color of this logo with the Razer Chroma app, and personalize your own notifications with it, too.

3 RAZER CORTEX

The Android 8.1 OS is thankfully stripped back, but there's a couple of apps present that are designed to help you get the most from this beautifully designed cell, including Razer Cortex. The main pull of this app is the curated list of games, including 120Hz titles that look awesome on this screen.

BEYOND RAY TRACING

Ray tracing is hot now, but is it practical yet, or even what we want?

"RAY TRACING is the holy grail of gaming graphics, simulating the physical behavior of light to bring real-time, cinematic quality rendering." That's the pitch from Nvidia for its Turing-powered RTX graphics cards, complete with their hardware ray-tracing cores. The company touts them as its "most important innovation in computer graphics in more than a decade." Big talk, but then ray tracing does offer jaw-dropping graphics, where every reflection, refraction, and shadow is rendered to pixel-perfect perfection. Who could not want to chase this?

Since the 1990s, games have used rasterization, a relatively simple way of turning 3D points in space into a flat image. It's not capable of being photo-realistic, but it can do a fairly good job, and do it quickly. Various tricks have added to the realism, such as shadow mapping, ambient occlusion, depth of field effects, and so forth. Graphics cards and APIs have been designed around accelerating the process ever since the 3dfx Voodoo moved over from the arcade machines in 1996.

However, advances have slowed over the last few years, the devices used to squeeze more realism out of the process are becoming more convoluted, and the huge jumps in visual quality made by games from 10 years ago have slowed down considerably. At its heart, rasterization is only a rough approximation of the world—it's based around objects, rather than light. Moving to a ray-traced model is a fundamentally different approach. ***–CHRIS LLOYD***

WORLD BUILDERS

After hardware, and then API support, you need a game engine. This is where we can see what is really feasible in the real world. These are the top ray-tracing engines so far.

Brigade

Something different from OTOY, Brigade is a real-time path-tracing game engine based on the company's Octane 4 rendering engine. It claims to be able to path trace scenes at 30–60fps, although nothing beyond demonstrations has appeared as yet. Interestingly, OTOY has a deal to integrate Octane into the Unreal Engine. This is worth watching, as we are jumping straight to path tracing.

Unreal Engine

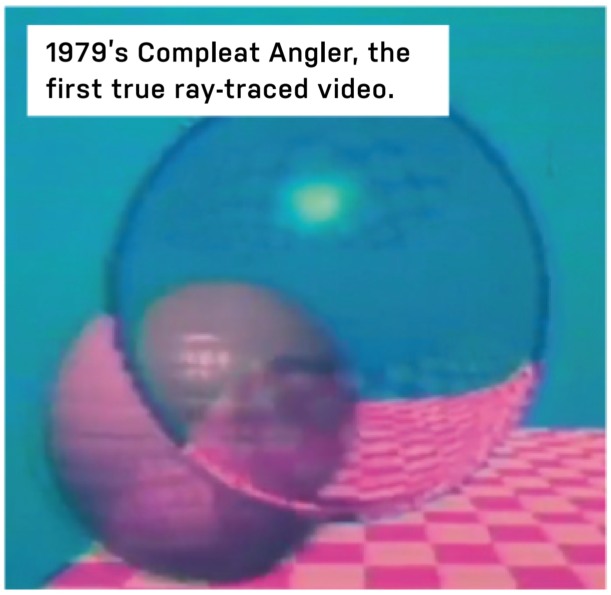
Developed by Epic Games, this first appeared in 1998, powering the FPS *Unreal*. It has been behind dozens of major titles since, and is now on version 4. The Unreal team has been working closely with Nvidia to incorporate RTX enhancements. Nvidia partnered with Epic to create some of its own showreels.

Unity

A huge cross-platform engine that boasts that it is used to produce half the world's games. It first appeared in 2005, powering Apple games, but it spread rapidly. Support for real-time ray tracing is supposedly on the way, but we have nothing beyond some vague rumors as yet.

Frostbite

This engine was developed by Electronic Arts, originally for the *Battlefield* series of games. Its latest incarnation supports ray tracing via Microsoft's DirectX Raytracing (DXR). Other Frostbite titles include *FIFA*, *Star Wars Battlefront*, and *Need for Speed*. Its *Battlefield V* is the first big title to support ray-tracing effects.



1979's Compleat Angler, the first true ray-traced video.

What most people think of if you mention ray tracing.

RAY TRACING is rendering technique that—and this is just the ridiculously quick and simple explanation—traces a path from an imaginary eye through each pixel on a screen, and calculates the color of the pixel when it intersects with an object. The more depth you build into the physical modeling of light, the more realistic it gets. Adding translucency, refraction, reflections, fluorescence, diffusion, and other optical properties all add complexity as more rays need to be cast at the scene.

To achieve decent results using such a method involves a lot of rays of light—thousands and thousands. The amount of math involved quickly multiplies alarmingly. Setting limits, such as the number of times a ray can be reflected, and the number of rays per pixel, can help keep rendering speeds to practical levels, but it remains a deeply computationally intensive task. There is always a compromise between speed and realism.

Ray tracing was born from ray casting, developed by Arthur Appel in 1968, a relatively simple system that cast a single ray into the scene to sample a pixel's color when it intersected with an object. This was expanded in 1979 to full ray tracing by splitting the ray at the point of intersection into three types: reflection, refraction, and shadow. The level of realism jumped hugely. Early demonstrations involved a lot of mirrored balls and checkerboard patterns. Rendering times were horrendous, and it remained a niche pursuit until the computational power it needed became widely available.

Ray tracing has a number of strengths over traditional methods. It excels at reflections, hence those mirrored balls. Rasterization engines can approximate these using environmental maps, which work well enough at long range, but when the object and reflective surface are close together, the effect starts to fall apart. Ray tracing produces accurate reflection out of the box, including reflections of reflections, something that is almost impossible using rasterization.

Transparency is another strong point. Adding this effect using rasterization requires complicated ordering of transparent polygons, and careful reference to the rendering orders. Ray-traced images handle this simply: Just set a material's transparency level, and the light rays fall into place. Shadows are similarly easily handled. No need for memory-intensive shadow maps. Lastly, there's the ease with which it handles curved surfaces—no need for tessellation,

NVIDIA
GEFORCE RTX

A hugely impressive demo from Nvidia, using the Unreal Engine.

the ray makes a true calculation with the mathematical position of the object.

These innate abilities of ray tracing to model light have lead to it being known as the ultimate in photo-realistic rendering. However, pure ray tracing, while capable of great accuracy in many areas, is not the apogee of rendering. It struggles with soft shadows, caustics (the envelope of rays reflected or refracted from curved surfaces, as seen from a glass of water in sunlight), and global illumination.

To achieve a true photo-realistic image, ray tracing on its own is not good enough. The best ray-traced images use other algorithms to cover the inadequacies, such as radiosity to create diffuse reflections, and photon mapping for caustics.

THERE IS A BETTER WAY

Path tracing is development of ray tracing, but the rays are bounced around the scene dynamically, collecting data as they go. Simply put (we're keeping it simple, as things can quickly get to the point where we need charts), path tracing goes deeper into the behavior of light, and fully traces the path of each ray as it intersects objects; instead of a matrix of straight lines, you get a complex set of zigzags. The ray collects data on color, material, and so forth, until it leaves the scene or is absorbed, and provides a final sample.

At each intersection, reflected rays are assigned random directions, assuming we haven't intersected a perfect mirror. At one ray per pixel, this creates considerable noise. The more rays per pixel you cast, the more accurate the final sample. Scenes set in sunlight require fewer SSPs (samples per pixel). Strong point lights in indoor scenes, a torch in a dark room, require many more SSPs to reduce the noise, as there's a low probability of the ray hitting a light source, which can skew the average figure if the SSP is set too low. As with ray tracing, using noise reduction can greatly improve the results; effectively filtering noise is a key way to accelerate the whole process. Nvidia's inclusion of neural network Tensor cores in its Turing architecture is why it can generate realistic shadows using only one or two SSPs, rather than hundreds.

The upshot of all these convoluted ray paths is a more optically accurate final pixel color than with ray tracing, and the ability to render a full range of lighting effects. For example, path tracing can employ different-sized lights, rather than simple points, giving realistic soft shadows. It can also generate caustics

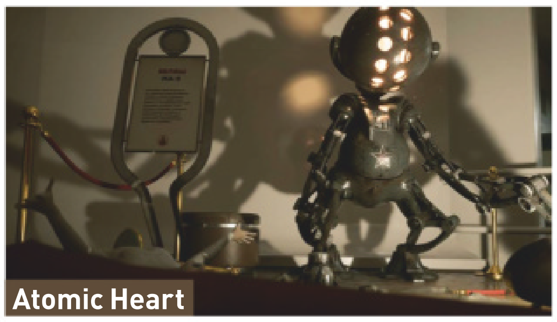
SHOW ME WHAT YOU GOT

Project Sol

Put together by a team at Nvidia, this demo reel shows masses of shiny high-tech machinery, with oodles of reflections and lighting effects, running in real time on an RTX 2080 Ti, using the Unreal 4 engine. Wow!

Metro Exodus

A first-person shooter from 4A Games, boasting beautiful RTX-enhanced graphics, including natural lighting, ambient occlusion, and realistic shadows. It uses 4A's own game engine.



Atomic Heart

Another FPS, this time set in a creepy alternate universe, *Atomic Heart* from Mundfish really pushes RTX with its lighting and reflections, including curved mirrors and mirrors looking into mirrors. It looks to be the most impressive of the first generation of games, if it delivers.

Battlefield V

The first big title to break with ray-tracing effects, *Battlefield V* supports DirectX Raytracing, and features enhanced explosions, reflections, and other lighting effects. It's our first real look at what ray tracing can add to games, but it's not the most extensive of implementations.

THE REAL COST

***Battlefield V* is the first game released to feature real-time ray-tracing effects. Specifically, it has been used to add reflections, rather than go the whole hog and try every effect. It looks good; certainly, the carefully selected demo videos show some very cool effects. So, it all works—the next big question is: How much performance does this extra polish cost in frames per second?**

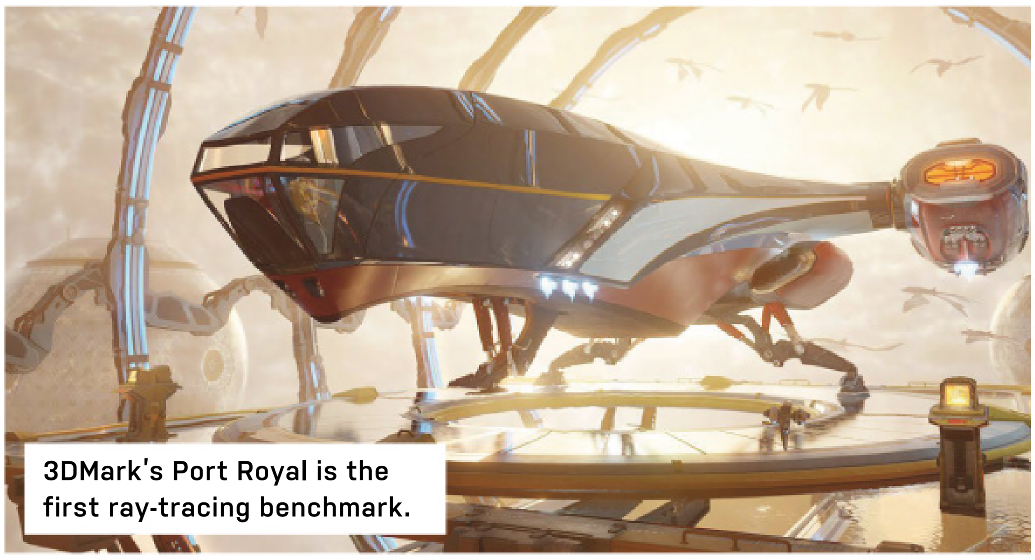
Running on a pretty chunky test rig, sporting an i7-8700, a 5GHz gaming monster, the good news is that if you stick to lower resolutions, such as 1080p, it is all perfectly playable in single-player. The bad news is that the frame rate hit is not insignificant. An RTX 2080 Ti runs at over 140fps without RTX, and drops to around 90fps with all settings at maximum. The RTX 2070, as you might expect, takes more of a hit. It drops from around 120fps to a little over 60fps.

If you start to crank up the resolution, things get worse; running at 1440p, frame rates drop toward half. If you insist on going full 4K, you will discover that those RTX-powered reflections cost, as near as makes no odds, half your frame rate. Ouch!

Multiplayer, where frame rates are really important if you want to remain competitive, proved a little more troublesome. There are also some known bugs, which caused frame drops. On an RTX 2070, the game chugs along at 40–50fps, but did stutter. To be fair, those stalls happened without RTX enabled, too, so the wrinkles are not just down to ray tracing. We are expecting patches soon.

So, not nearly as bad as some have been forecasting, but by no means insubstantial. And this was on a heavyweight rig. However, it is an emerging technology, and this is the first game, so we can hope things will get better, but it is safe to say that ray tracing will put a considerable strain on your system. As ever, it'll be a balancing act between frames rates, resolution, and graphics settings.

Accurate reflections are where ray tracing scores big.



3DMark's Port Royal is the first ray-tracing benchmark.

effectively, and color-bleeding, motion blur, depth of field, and other optical effects are much easier. It's still not a completely accurate model of the way light behaves in the real world—a tall order—but at its best, path tracing can produce images that are virtually indistinguishable from photographs. The cost? Processing power. Lots and lots of it.

Path tracing's ability to naturally create effects that have to be simulated or added into ray-traced images, and its fundamentally unbiased rendering (it doesn't introduce any systematic error or bias in the results) mean that path-traced images are often used to create reference images to test the effectiveness of other rendering methods. It is pretty much as good as it gets.

Path tracing was originally developed by James Kajiya in 1986. The process has been developed gradually over the years, including the addition of a global illumination algorithm in 2002. The first commercial demonstration of a GPU running path tracing was made by Nvidia in 2009. Since then, it has found its way into programming toolkits, including CUDA, OpenCL, and OptiX.

Path tracing is widely used in movies and television, and is now pretty much the standard rendering method for animation and visual effects. Pixar's *Toy Story* from 1995 used a scan-line algorithm (a rasterization method), with shadow and reflection maps to add realism. Later systems then added elements of ray tracing—two shots of a glass bottle appeared in 1998's *A Bug's Life*, for example. By 2006, the movie *Cars* added ray-traced elements to the entire movie, specifically to create realistic reflections and shadows. Since then, the entire industry has been moving across to path-traced rendering engines, which can generate the required levels of realism without resorting to additional tweaks and trickery. You've been watching path-traced television and movie effects for the last 10 years now.

Where does this leave Nvidia's boasting? Touting real-time ray tracing as the holy grail of graphics is an understandable piece of showmanship on Nvidia's behalf. But let's be honest, we haven't been sold whole-scene real-time ray tracing at all. We have selected elements of ray tracing to add features that traditional rasterization struggles to emulate. Strictly speaking, we have a hybrid system. Ray tracing takes a huge amount of processing power, so it makes

OTOY's OctaneRender: At its best, path tracing is almost photographic.

sense to play to its strengths, and limit it to where it can add something new.

Nvidia's RTX and Microsoft's DirectX Raytracing add shadows, reflections, area lighting, and ambient occlusion. Which is plenty to do—a fully ray-traced rendered scene capable of running at game speeds is still way beyond the capabilities of any card. Traditional rasterization isn't going anywhere yet. What we have is a new set of tools and tricks to add realism and sparkle. It may not be the big jump we were hoping for; it is, however, a decent first step on the road from rasterization to ray-traced rendering and beyond. Rasterization is fast, but it needs clever trickery to be realistic. Ray tracing (and path tracing) is inherently realistic, but needs clever trickery to achieve quickly.

ON THE RIGHT PATH

Looking at rendering engines in the movie industry is revealing. It has also used hybrid systems, balancing speed and efficiency, and growing in realism. And it shows where we want to go: path tracing, which delivers levels of realism that verge on the uncanny. If anything deserves to be called the holy grail of graphics, this does.

We are at an interesting point. We can see what we want, but, as ever, hardware lags behind our math. The rhetoric used to sell real-time ray tracing may be a little grandiose, and the results patchy, but let's not be too churlish. Things just got more realistic, and will only get better.

Entire-scene path tracing is on the verge of being possible in near real time, albeit running specialist software on pretty chunky multiple-card systems. In a year or two, it will be possible on a high-end desktop. The end of the line for rasterization is coming. The tricks and hacks each generation requires to improve on it are becoming more complex, and the results are diminishing. It can never approach the realism of ray and path tracing, however much time and effort is spent.

A period of hybrid systems is inevitable, given the huge investment already made in games, but it is a stopgap. Nvidia had to divert much of the Turing architecture to maintaining its rasterization performance. At some point, the jump will be made to a system built from the ground up to ray trace, or better yet, path trace. Quite possibly on a closed system first, such as a console. As the movie industry moved on, so will games. Nvidia has opened the door a crack—the next two years will see it being thrown wide open.

THE OTHER GUYS

OK, Nvidia has been hogging all the limelight so far, but let's not forget AMD. It has its own ray-tracing engine, called Radeon Rays, "high-efficiency, high-performance GPU-accelerated ray-tracing software." AMD is taking a slightly different approach to Nvidia, concentrating on ground-up software support. Radeon Rays is open source, based around OpenCL, and as such is platform and OS independent. We've yet to see Radeon Rays in a game, but it has quietly been gathering support; importantly, it is due to be integrated into Unity's GPU Progressive Lightmapper, a hugely influential game engine.

The next question is: Does AMD have a hardware response to the RTX series? Nvidia has the edge in performance, but that doesn't equate to profit. Radeon cards have carved out a large chunk of the sub-$300 market, which shift in real numbers. The Navi GPU architecture is in the wings, and rumor has it that AMD will want to keep prices keen ($130 for an RX 3060, through to $250 for an RX 3080, if one popularly quoted leak is to be believed). However, it looks like hardware ray tracing is off the menu for now (unless AMD is being very tight-lipped). But at its heart, ray tracing, and path tracing, is all math, and scales beautifully with multiple GPUs, so you can keep things simple if you wish.

It may be a smart move to let Nvidia take the early hits in getting hardware ray tracing going. The architecture after Navi will be the one to watch if AMD plans to jump aboard this particular wagon. Until then, it appears content to build software support, especially for its professional ProRender technology, and concentrate on delivering a competitive level of performance per dollar in its cards. Real-time ray tracing is still very much a novelty, and few have the hardware to use it. A fast rasterization engine is what the mainstream market is going to be shopping for, for a while yet.

ALL THE TUTORIALS, AND ADVICE YOU NEED TO SUCCESSFULLY INSTALL AND USE UBUNTU.

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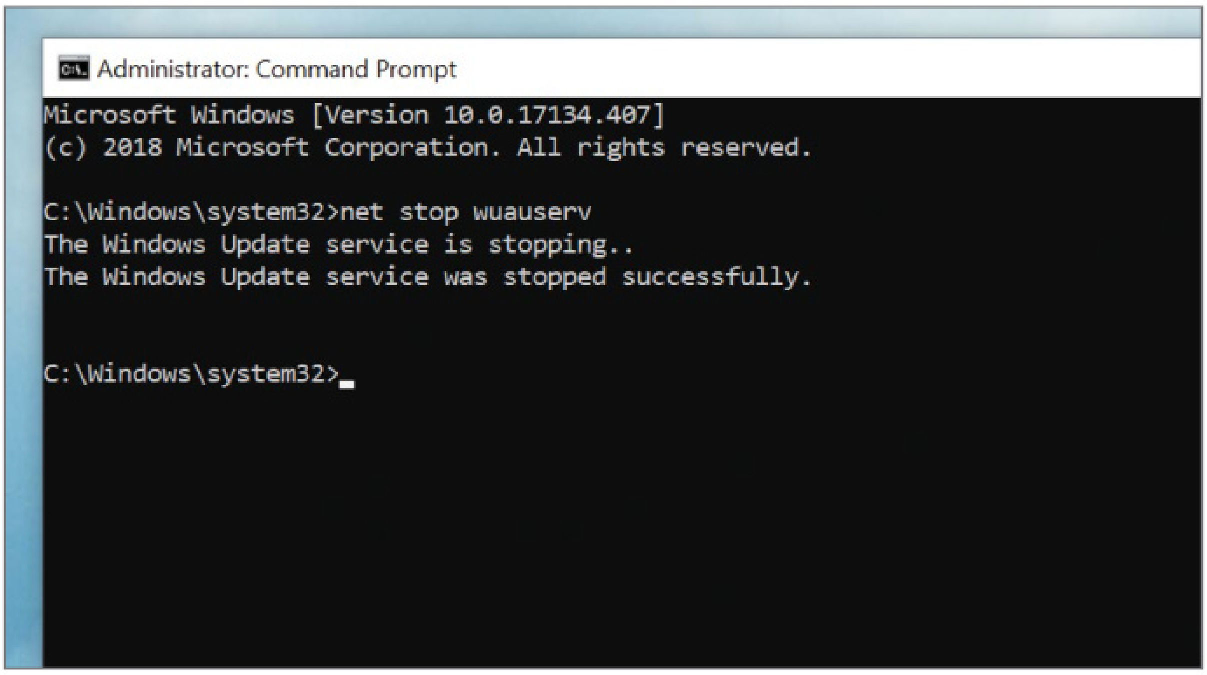
HOW TO

STEP-BY-STEP GUIDES TO IMPROVING YOUR PC

TIP OF THE MONTH



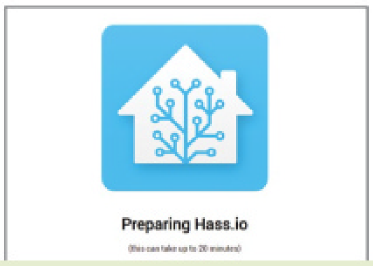
Administrator: Command Prompt

```
Microsoft Windows [Version 10.0.17134.407]
(c) 2018 Microsoft Corporation. All rights reserved.

C:\Windows\system32>net stop wuauserv
The Windows Update service is stopping..
The Windows Update service was stopped successfully.


C:\Windows\system32>_
```

STOP WINDOWS UPDATE IN ITS TRACKS

Ever been so fed up with Windows Update you want to kill it? We know we have. When it comes to testing old machines and benchmarking processors, having Windows suck up resources by downloading and extracting updates over a single thread is truly frustrating. To stop it manually, open a command prompt as an administrator, type "netstop wuauserv," hit Enter, and it stops from Windows updating, at least until the next restart.

MAKE – USE – CREATE



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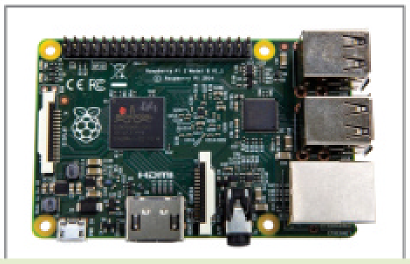
Take control of your smart home using Hass.io



64
Set up a home security system with a Raspberry Pi

70
How we transformed a machine with a multicore upgrade

ZAK STOREY
DEPUTY EDITOR

JUST OVERCLOCK IT

I'm going to rock out of this magazine in exactly the same way I rocked up to it. In my first ever issue, I wrote two features: one on overclocking and another on mobos with USB 3.1 Type C (don't ask). The former subject is still incredibly important to me, and it should be to you, too.

I get it: Overclocking isn't for everyone. It can be tough and frustrating. You need a decent cooler, good airflow, an unlocked processor, and enough time to grasp those pesky BIOS settings. And if things go wrong? Well, just ask the Ryzen 7 1800X I accidentally put twice as much voltage as normal into, then forced to run three instances of Cinebench R15.

But when you get it right—what a feeling! The waves of elation when you break down those barriers, or score higher in Cinebench than you thought possible, are difficult to describe.

Ultimately, though, none of that matters. What does matter is that whatever you do, you enjoy it. Because if you don't, what's the point? Whatever you do with your rig, try to have fun with it. Mess around with settings, themes, performance tweaks, cooling, ridiculous lighting, and car hoses. Yeah, a PC is a tool, but it can be so much more.

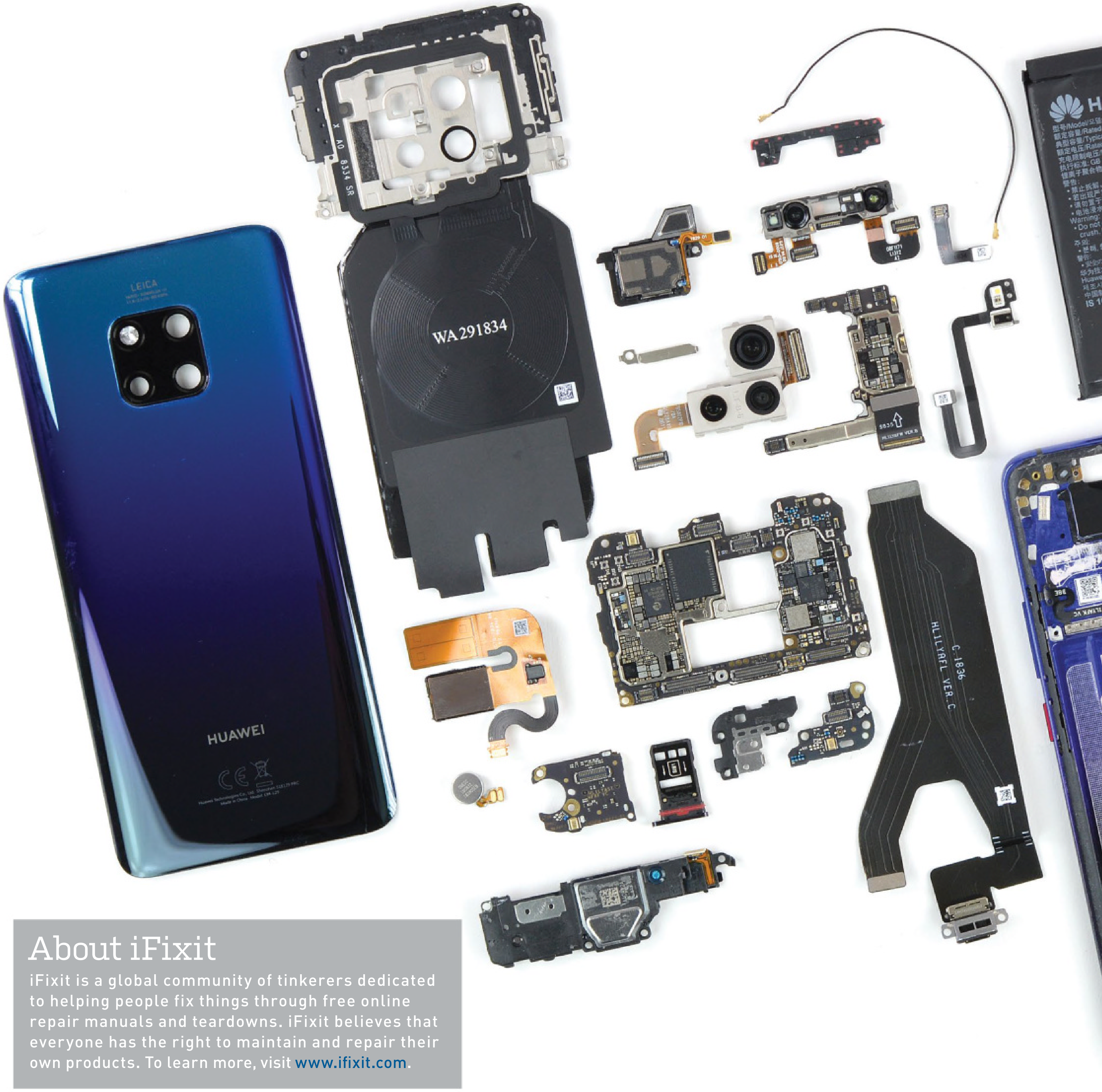
↘ submit your How To project idea to: comments@maximumpc.com

IFIXIT presents:

AUTOPSY

THIS MONTH WE DISSECT...

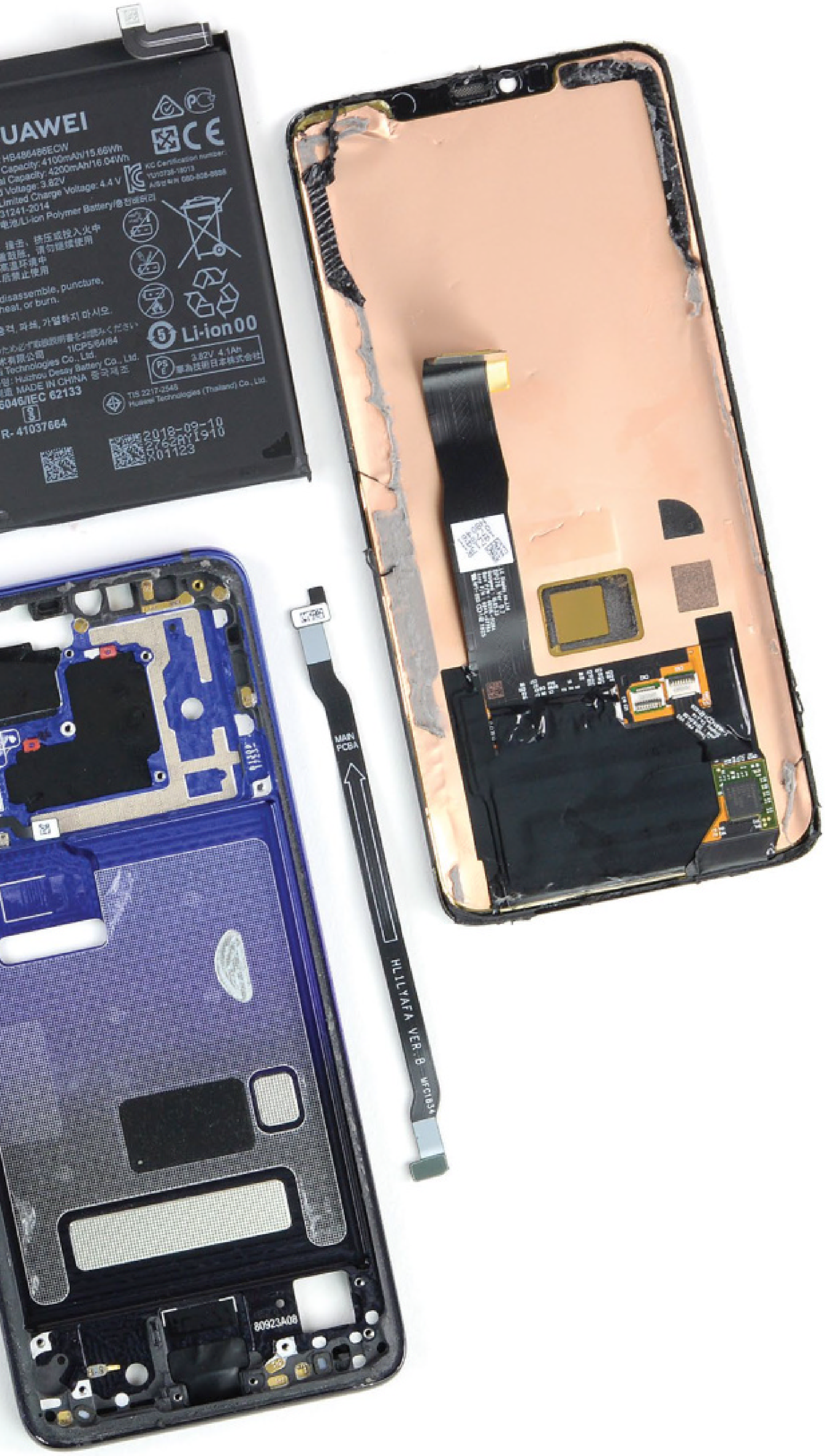
Huawei Mate 20 Pro



About iFixit

iFixit is a global community of tinkerers dedicated to helping people fix things through free online repair manuals and teardowns. iFixit believes that everyone has the right to maintain and repair their own products. To learn more, visit www.ifixit.com.

We had to use a pair of tweezers to dig out the last bits behind the motherboard.



BACKGROUND

In the middle of the finale of last year's flagship smartphone season, Huawei threw its last big fighter into the ring: the Mate 20 Pro. On paper, it looks more powerful than ever, but only a teardown will tell if it's a true champ or just a poser.

MAJOR TECH SPECS

- 6.39-inch 3120x1440 (538 ppi) AMOLED display
- Huawei Kirin 980 chipset: Mali-G76 MP10 GPU and an octa-core CPU (2x 2.6GHz Cortex-A76 cores, 2x 1.92GHz Cortex-A76 cores, and 4x 1.8GHz Cortex-A55 cores)
- Triple rear cameras: 40MP f/1.8, 20MP f/2.2, and 8MP f/2.4 lens with 5x optical zoom
- 24MP f/2.0 selfie cam
- IP68 dust/water ingress rating
- Android 9.0 (PIE)
- Facial recognition, plus under-display fingerprint sensor

KEY FINDINGS

- The Mate 20 Pro sports a notched, curved display—the notch has grown compared to that of the P20 Pro, making space for the new sensors needed for the 3D face unlock feature, and the rear fingerprint sensor has been swapped for a third camera. It's dressed in the industry-standard glass sandwich, but Huawei has applied a non-slip, fingerprint-resistant coating to the rear glass to help prevent slippery accidents. The Mate 10 Pro's loudspeaker holes give way to the Mate 20 Pro's SIM and NM card tray.
- Heat helps the Mate 20 Pro relax before our standard tools finish the job of removing the fragile rear glass panel. Thanks to the relocated fingerprint reader, there's no danger of tearing delicate flex cables in the process.
- We instantly face off against the new bi-directional wireless charging coil—both a transmitter and receiver. Huawei wants you to use it to charge its AirPods competitor, Freepods. Eight screws later, we remove the midframe assembly, home to the wireless charging coil, NFC antenna, and dual-LED dual-tone flash.
- Nine flex cables hold the motherboard in place, plus an antenna cable. Like the P20 Pro, the Mate 20 Pro sticks to a small mobo, leaving room for a wider battery. With the 3D face unlock hardware and triple rear camera taking up more motherboard space than usual, Huawei had to cut some camera holes and change the layout a bit.
- To our surprise, we find some orange pull tabs on the left side of the battery, containing a short guide on how to remove it. We're happy whenever we can extract a battery without having to break out our iFixit Adhesive Remover—we just needed a little help from an iOpener. The battery weighs in at a mighty 16.04Wh (4,200mAh at 3.82V).
- Repairability score: 4 out of 10 (10 is easiest to repair). Many components are modular and can be replaced independently. Battery replacement requires removing only the back panel and midframe. Only standard Phillips screws are used, with an average amount of adhesive. There are more flex connectors than average, and repairs will consume more time. Glued-down front and back glass means greater risk of breakage, and makes repairs tricky to start. Screen repairs require a lot of disassembly while battling adhesive. A broken screen probably means you need to replace the fingerprint reader, too, or vice versa. ⏻

Take Control of Your Smart Home

YOU'LL NEED THIS

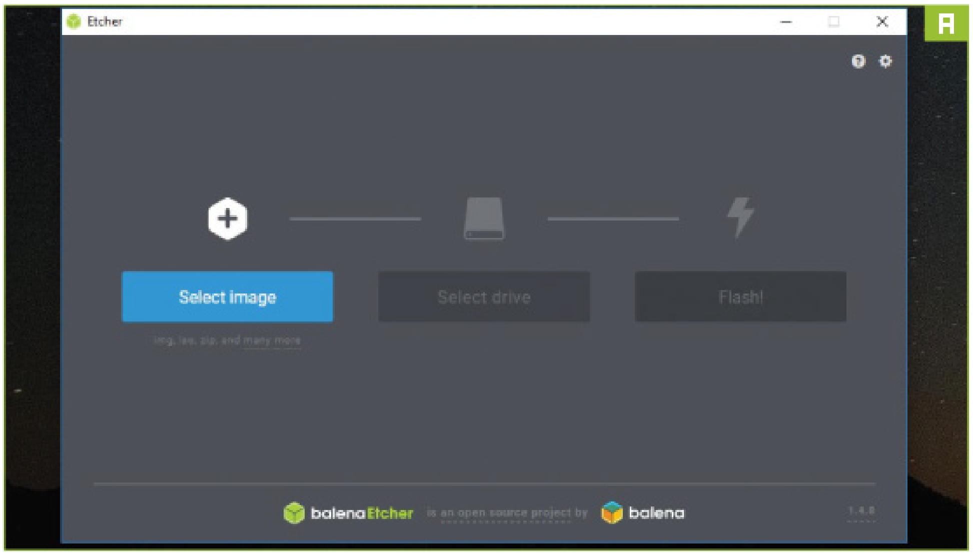
HOME ASSISTANT

Find the right version for your hardware at www.home-assistant.io.

A RASPBERRY PI

Does it have to be a Pi? No. But Home Assistant works best on one.

SMART HOME EQUIPMENT IS, almost without exception, utterly unfriendly. It's unfriendly to you, forcing you to use a certain app to activate it, and possibly feeding your data back to goodness-knows-who, and it's (usually) rather hostile toward smart gear from other manufacturers. As you might expect, this kind of behavior doesn't wash well with us. If we're getting smart, we want to be able to manage that equipment in a smart way. Home Assistant (or Home-Assistant.io or, to give it yet another name, Hass.io) is the solution, at least for want of something less clunky. Install it on a Raspberry Pi—in our case, we're using a Pi Zero W, which probably doesn't have quite enough power, but it does work, and it's incredibly cheap—or on just about any hardware you have to hand (there's a Windows version available, if you have an always-on PC), and you'll be able to control your gear from a web interface, set up your own custom automations, and much more. It's not as easy or, honestly, as convenient as an app, but it's a darn sight better than being forced to use a suite of apps, and the level of additional control makes working with Hass.io more than worth the extra effort. **–ALEX COX**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Etcher
Select image
img, iso, zip, and many more
Select drive
Flash!
balenaEtcher is an open source project by balena
1.4.8

1 INSTALLATION

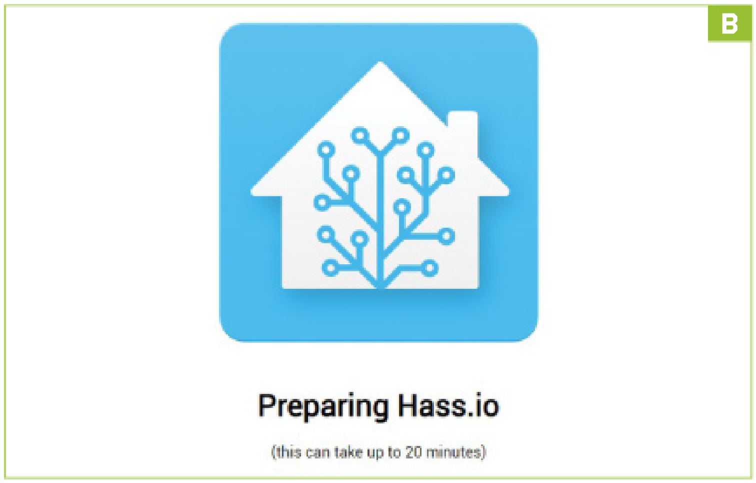
As we've mentioned, we're working with the Raspberry Pi version of Home Assistant here—if you're looking to install it on a different platform, the Home Assistant site at http://hass.io has more information, but bear in mind that non-Pi versions can be less secure and less feature-complete, because the mini computer is the app's primary target. Dig up a spare Class 10 SD card of around 32GB, and download Etcher (http://etcher.io), which has quickly become the de facto best SD card writing app, surpassing Rufus and the venerable Win32DiskImager. You'll find the disk image you need for your particular Pi version at http://home-assistant.io/hassio/installation, and writing said image using Etcher is a simple task [**Image A**]. However, you can't necessarily write your card and call it done. You also need to grab a USB stick to set up your network credentials—there's no interactivity on the Raspberry Pi directly (it's all done through the web interface), and a static IP address is a must in order to access Home Assistant from a consistent URL. Format the USB stick, name it "CONFIG," create a folder named "network," and create a blank text document called "my-network" with no extension inside that. The exact contents of this depend on your network, so refer to the official docs at http://bit.ly/2QfZm4o to get it right—you need your SSID and network password (if you're going to connect via Wi-Fi), along with the static IP address you'd like to use, and the IP address of your router or gateway.

2 FIRST BOOT

It's not required, but you may want to hook up a monitor the first time you launch Home Assistant, to see the streaming list of status messages as it goes through that initial configuration. You'll notice that it creates a Docker container, and runs from within that—it's a good way of making the most of the RPi's resources, scaling back when you're not taxing it. Don't be alarmed if it seems to stall, because Home Assistant needs about 20 minutes on first boot to configure itself. Head to your main PC, open a web browser, and point it to "<your static IP>:8123" or, if your router supports mDNS, "hassio.local:8123" will take you to the same place. Now wait—the holding page [**Image B**] will update and bring you to the main interface when Home Assistant has done what it needs to do. If it doesn't, or if it drops out, manually refresh the page. Barring any issues writing the SD card—and Etcher will have caught these in its verification step—you'll soon see the registration screen, where you'll set up your local account. Throw in your details, then log in with the account you just set up.

3 BASIC SETUP

Home Assistant's initial interface couldn't be more underwhelming. You'll see a brief intro card, and two symbols, one telling you if it's day or night, and a mildly mysterious "yr" weather symbol. This is



Preparing Hass.io

(this can take up to 20 minutes)

actually from Norwegian weather service Yr.no, but neither symbol represents your current location. That's something you need to configure yourself. Hit the hamburger menu in the top-left corner of the interface, and head to "Configuration → Customization." Home Assistant thinks you're at 0 latitude and 0 longitude—which, unless you live in the sea off the west coast of Africa, you are not. Open a new tab and use www.latlong.net to find your real co-ordinates. Click the pencil icons on Home Assistant's "Customization" tab, and enter each one, then click "Save." Head to the "Map" tab to check your new location has sunk in, then go back to the "Configuration" menu.

›› Let's get your smart gear listed on the main screen, because Home Assistant's most core function is to provide an interface for you to control that equipment. It's not compatible with everything, and it doesn't have every single function, but it's easy enough to switch things on and off to begin with. Click the "Integrations" option, and look for your equipment in the list; this isn't confined to smart home devices, as we'll come to later. Click the "Configure" button next to your chosen device ecosystem—LIFX, for example, for one or more bulbs from that one company—and hit "Submit" [**Image C**]. Home Assistant generates the relevant config file for you; click "Close," then head back to the main "Overview" screen to see a card for your gear. If it's something switchable, you can use those switches to activate or deactivate that equipment. If you've attached something like a Google Cast device, you can see the thumbnail, transport controls, and further options on the bottom-right menu.

4

GOING DEEPER

If you've integrated a light device, such as LIFX or Philips Hue, you can do more than just toggle it. Head back to "Configuration → Integrations," and you'll now see your device broken out of the main list and placed at the top. Click it to see your individual devices laid bare—take a note of their entity names, which are displayed at the bottom of each card, before we move on. Now select one of the individual devices from that family to see its deeper configuration options, such as tweaking the color, temperature, or brightness [**Image D**], or even activating an "Effect," something we cannot in good conscience allow you to do. Click the cog, and you can give your light a better name than the one you entered when hurriedly setting it up in the associated smartphone app, which is reflected in the list on the "Overview" screen. You don't have to dig in this deep to get to the advanced controls, either; just click the device's icon on the main screen, and the advanced control panel pops up.

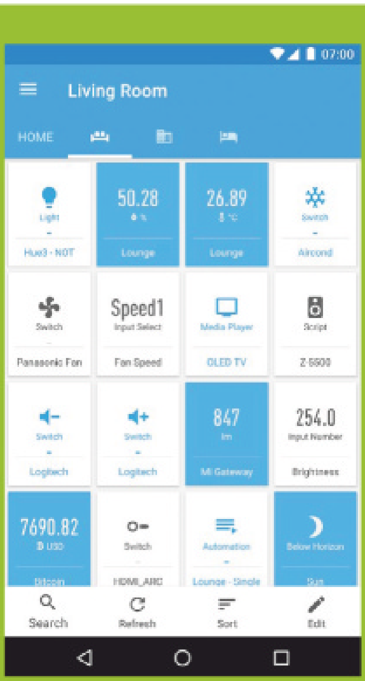
5

GOING AUTOMATIC

We're not going to argue that Home Assistant's automation section isn't baffling—it really can be difficult, because it's deeper than a very deep thing—but it's more than possible to just get your feet wet, piecing together simple automations without a degree in JSON coding, then go up to your knees and beyond at a later time. So, let's do something easy, and set a timer. Open up "Configuration → Automation," and hit the yellow plus icon in the bottom-right corner to start creating a new automation. Give it a name and, in the trigger section, set the trigger type to "Time." Enter a military time value in the "At" field, separated by colons; 19:00:00, for example, sets it at 7 p.m. precisely. You can use conditions, which are only checked when the trigger fires, to further specify the situation in which you want something to happen—perhaps you'll choose "Sun" as a condition, and set your light to only switch on if it is both 7 p.m. and after sunset, if you're feeling clever, or perhaps you'll check to see if a light is on before switching it off—but they are entirely optional if you're more inclined to create a simple automation. You can add as many triggers and conditions (and, indeed, actions) as you like, but bear in mind that adding more than one trigger causes the automation to fire whenever any of those triggers occurs—only the conditions section allows it to be selective.

›› We now need to determine what we want to actually happen. Doing something simple such as switching a light on or off is only slightly obtuse; set the action type to "Call service," then use the "Service" drop-down to select the kind of light trigger you'd like to use—in our case, we'll select "light.turn_on." Now we need to set which of the nebulous entities around our home we'd like to activate. On the "Integrations" screen, which

GO MOBILE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254.0
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Bitcoin
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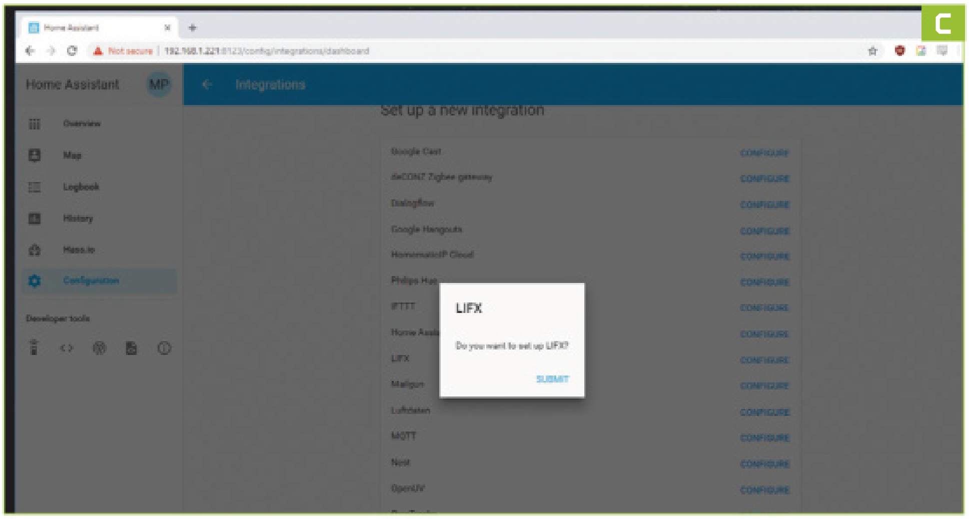
HDMI_ARC
Automation
Lounge - Single
Below Horizon
Sun
Search
Refresh
Sort
Edit

We may have railed against the trend for smart gear to require smartphone control, but let us do a 180: If you've put the effort into getting Home Assistant up to spec, a quick-to-access interface for those non-savvy members of your household is worth its weight in gold. There are apps for Home Assistant on both Android (look for HomeAssist on the Play Store) and iOS, with the latter (surprisingly) probably even better supported than the former, particularly once you've enabled the Home Assistant iOS integration in the web interface's "Configuration" menu. Communication goes two ways; you'll be able to take control of all of the entities you've set up in Home Assistant—and that means gear from a host of different manufacturers, controllable in one place—as well as set up push messages to go to your iOS device, and perform location tracking. Install the iOS integration to get started. Admittedly, Apple's own Home app and the Eve Homekit app offer a better experience if you're using Homekit-compatible devices, but Home Assistant's results are your own—and that counts for a lot.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Overview
Map
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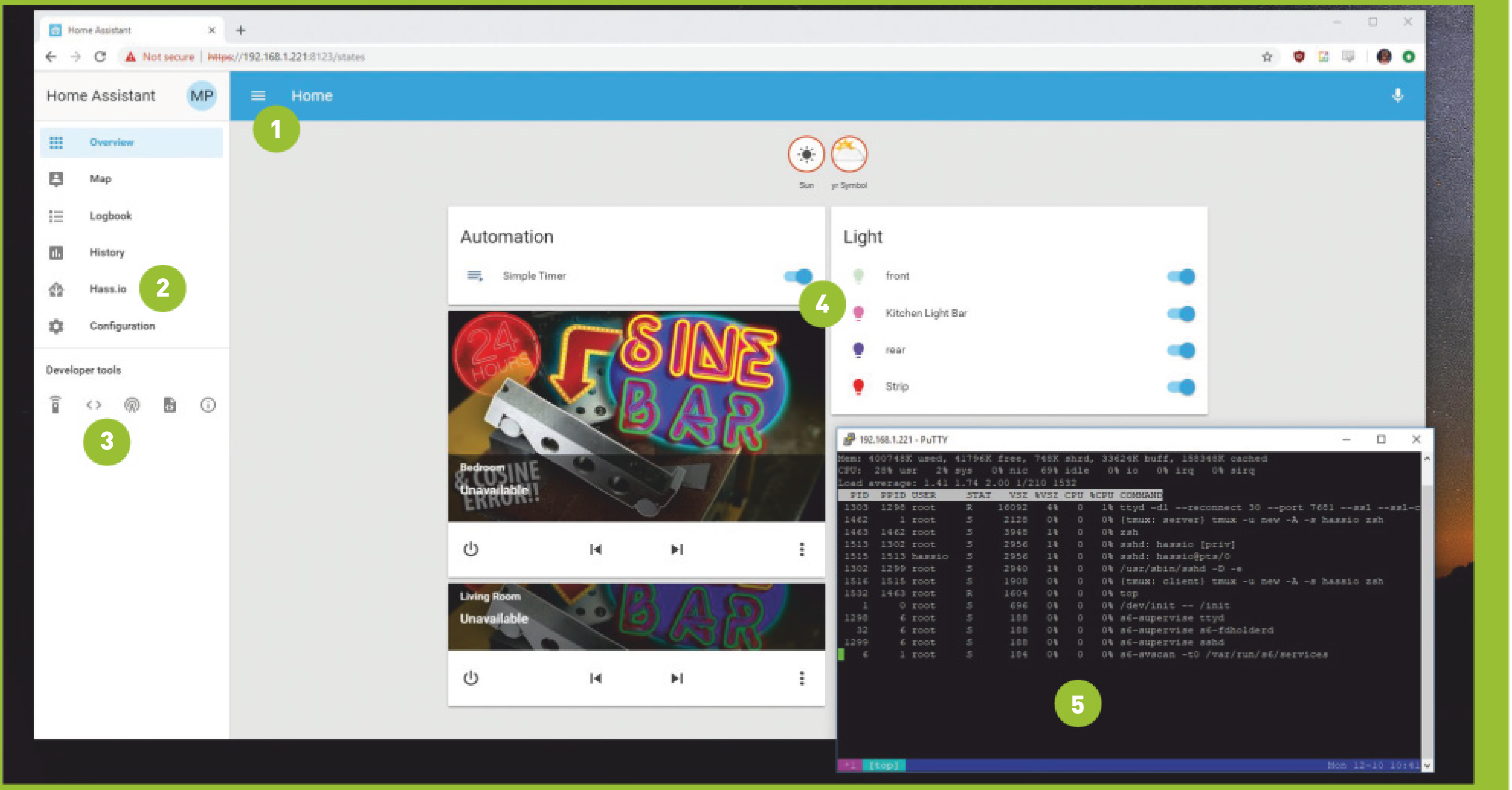
Configuration
Developer tools
Integrations
Set up a new integration
Google Cast
deCONZ Zigbee gateway
Dialogflow
Google Hangouts
HomematicIP Cloud
Philips Hue
IFTTT
Home Assistant
LIFX
Mailgun
Luftdaten
MQTT
Nest
OpenUV
CONFIGURE

LIFX

Do you want to set up LIFX?

SUBMIT

AROUND HOME ASSISTANT


Home Assistant
Not secure
https://192.168.1.221:8123/states
Home Assistant
MP
Home
1
Overview
Map
Logbook
History
Hass.io
2
Configuration
Developer tools
3
Sun
yr Symbol
Automation
Simple Timer
4
Light
front
Kitchen Light Bar
rear
Strip
Bedroom
Unavailable
Living Room
Unavailable
192.168.1.221 - PuTTY
5

```
Mem: 400748K used, 41796K free, 748K shrd, 33624K buff, 158348K cached
CPU:  28% usr   2% sys   0% nic  69% idle   0% io   0% irq   0% sirq
Load average: 1.41 1.74 2.00 1/210 1532
  PID  PPID USER     STAT   VSZ %VSZ CPU %CPU COMMAND
 1303  1298 root     R     16092   4%   0   1% ttyd -dl --reconnect 30 --port 7681 --ssl --ssl-c
 1462     1 root     S      2128   0%   0   0% {tmux: server} tmux -u new -A -s hassio zsh
 1463  1462 root     S      3948   1%   0   0% zsh
 1513  1302 root     S      2956   1%   0   0% sshd: hassio [priv]
 1515  1513 hassio   S      2956   1%   0   0% sshd: hassio@pts/0
 1302  1299 root     S      2940   1%   0   0% /usr/sbin/sshd -D -e
 1516  1515 root     S      1908   0%   0   0% {tmux: client} tmux -u new -A -s hassio zsh
 1532  1463 root     R      1604   0%   0   0% top
    1     0 root     S       696   0%   0   0% /dev/init -- /init
 1298     6 root     S       188   0%   0   0% s6-supervise ttyd
   32     6 root     S       188   0%   0   0% s6-supervise s6-fdholderd
 1299     6 root     S       188   0%   0   0% s6-supervise sshd
    6     1 root     S       184   0%   0   0% s6-svscan -t0 /var/run/s6/services
[1] [top]                                                              Mon 12-10 10:41
```

1. MENU MATTERS
This is what we call a hamburger menu. Click its delicious pixel meat or pixel buns to open or close the menu bar.

2. EXTRA GOODIES
The "Hass.io" menu is your gateway to a realm of add-ons that will make your Home Assistant install even cooler.

3. BIG GUNS
Do you feel like getting a little experimental? Then take a look at the developer tools, which can help you test commands before you plumb them into automations.

4. WHAT'S GOING ON?
All of your devices, and their critical controls, are shown on different cards in the "Home" menu.

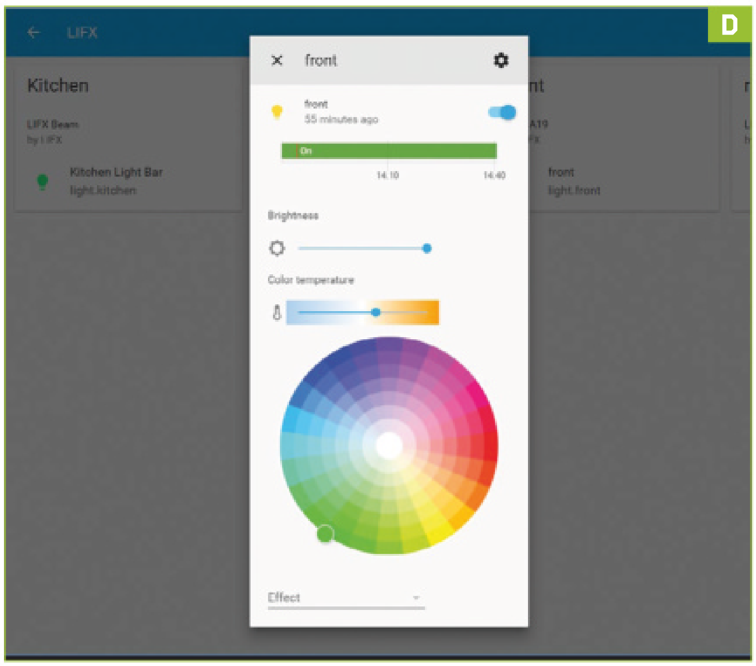
5. COMMAND LINE
If you install the SSH add-on, you can use PuTTY, or similar, to access the Home Assistant shell. In this instance, we're running "top" to keep a watchful eye on our overheads.

we looked at earlier, you'll have noted the entity names of your devices; enter {"entity_id":"light.front"} (substituting "light.front" for the name of the entity you actually want to control) in the service data section. You can, again, get more complex with this, but it's enough for now. Click the save icon in the bottom-right corner (check the top of the page for any errors if it doesn't work), then head back to the "Overview" screen. Your new automation appears in a card. You can toggle it on or off with the switch, which stops the trigger from firing; click the icon to the left, and you can test that the action actually works.

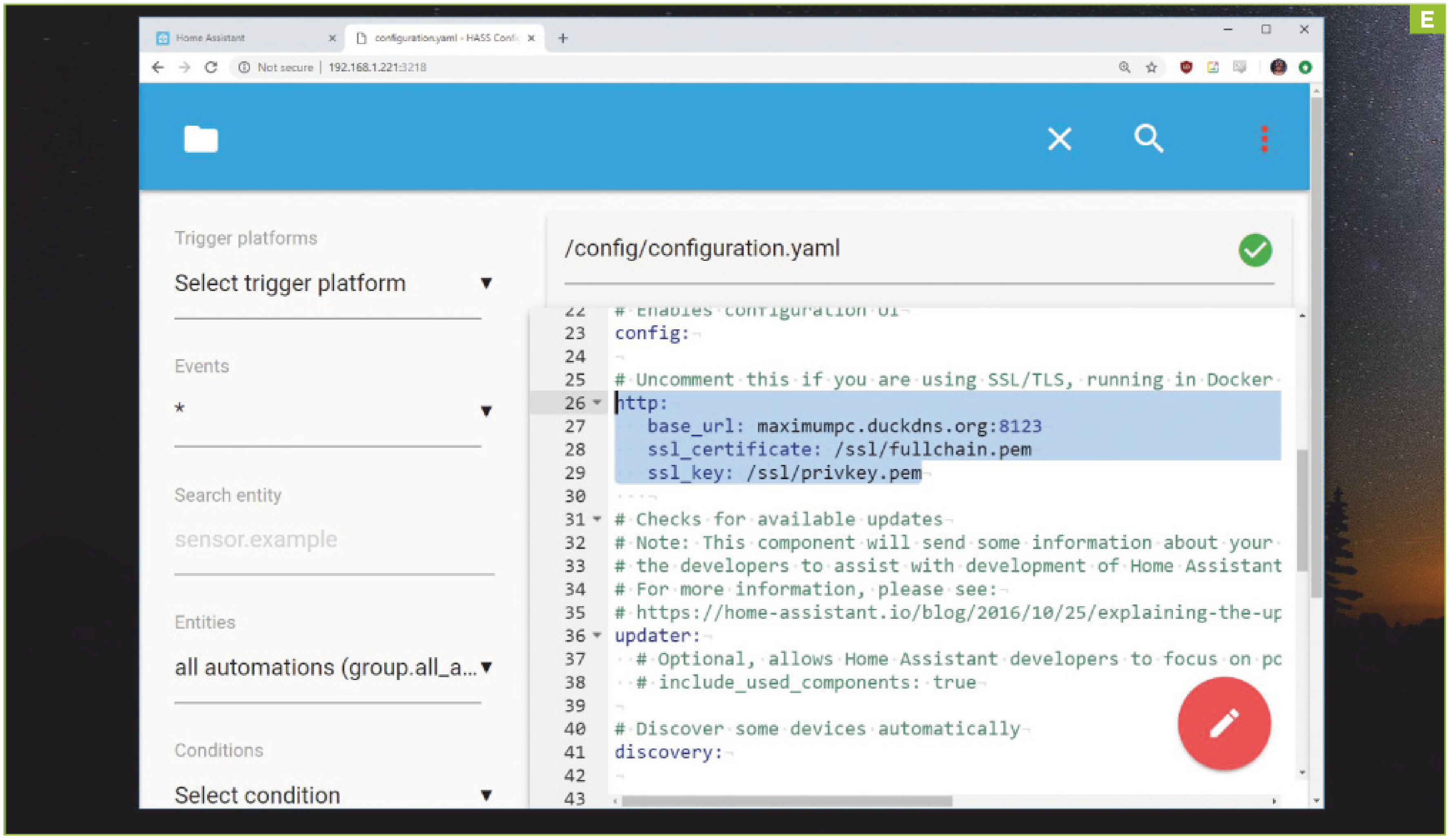
» That's as far as we'll go on automations in this tutorial; Home Assistant's documentation goes into much more granular detail, and there's a whole scripting language to learn if you want to take super-fine control.

6 SERVE IT UP

If you want to gain access to Home Assistant from outside your home (and, let's face it, you do), or use tools such as IFTTT to increase your automation potential, you need to do a little extra finagling. First, head over to www.duckdns.org and sign up for an account with the DNS forwarder service; this is what we'll use to send a human-readable URL to your Home Assistant server. Choose your subdomain, click "add domain," and Duck DNS should detect your home IP, and list it in the bottom-left box. Keep this page open, and head back to your Home Assistant interface. Go to "Hass.io → Add-on Store," click "Duck DNS," and click "Install." Wait for it to do its thing. Once it's safely installed, head down to the "Config" section. Change "accept_terms" to "true," paste the token from your Duck DNS page, surrounded by quotes, in place of the appropriate null value, then add your generated Duck DNS domain (again, in quotes) in place of the "domains" null value. The text turns red if


D
LIFX
Kitchen
LIFX Beam
Kitchen Light Bar
light.kitchen
front
front
55 minutes ago
On
14:10
14:40
Brightness
Color temperature
Effect
front
light.front

E


Home Assistant
configuration.yaml - HASS Confi
Not secure | 192.168.1.221:3218

Trigger platforms
Select trigger platform

Events
*

Search entity
sensor.example

Entities
all automations (group.all_a...

Conditions
Select condition

/config/configuration.yaml

```
22 # Enables configuration UI
23 config:
24
25 # Uncomment this if you are using SSL/TLS, running in Docker
26 http:
27    base_url: maximumpc.duckdns.org:8123
28    ssl_certificate: /ssl/fullchain.pem
29    ssl_key: /ssl/privkey.pem
30
31 # Checks for available updates
32 # Note: This component will send some information about your
33 # the developers to assist with development of Home Assistant
34 # For more information, please see:
35 # https://home-assistant.io/blog/2016/10/25/explaining-the-up
36 updater:
37   # Optional, allows Home Assistant developers to focus on pc
38   # include_used_components: true
39
40 # Discover some devices automatically
41 discovery:
42
43
```

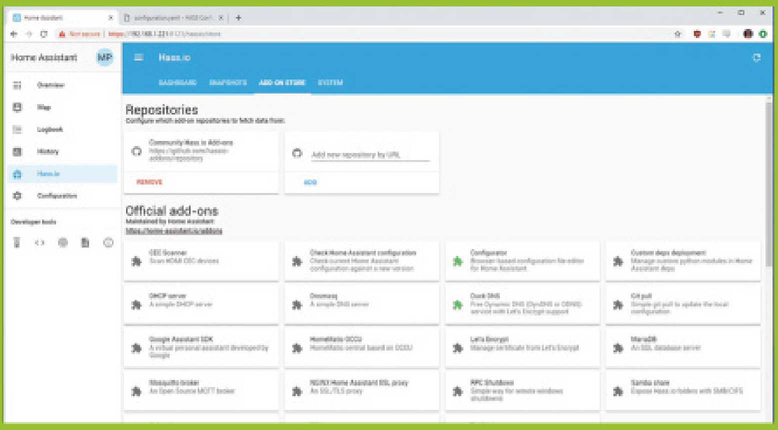
it's parsed incorrectly. Click "Save," then click "start" above to start the Duck DNS service running—it generates your SSL keys, which takes some time, so while you wait, head to your router's configuration panel, and forward ports 8123, 80, and 443 to your Home Assistant box. You'll be able to access Home Assistant from <yourdomain>.duckdns.org:8123.

7 ADDING SSL

However, that's horribly insecure, and we can't let you leave it like that. Return to the Add-on Store, and this time install Configurator, a tool that allows us to get down and dirty editing Home Assistant's internal config files. Add a password (in quotes) to the config section, save it, start the extension as before, then head to <your home assistant ip>:3218 and sign in with the credentials you just set. Click the folder icon, top-left, then select "configuration.yaml." Head to line 26, uncomment "http:" and the line below it, then change "example" for your Duck DNS subdomain. Create a new line underneath headed with three blank spaces, and add the line "ssl_certificate: /ssl/fullchain.pem," then create another similarly spaced line containing "ssl_key: /ssl/privkey.pem" [Image E]. Return to the "Configuration" menu, go to "General," and click "Check Config." If all is good, scroll down, and hit the red "Restart" button.

›› Take a breath: We should now be good to go. You can drop the port forwarding for ports 80 and 443 (keep 8123) in your router while you wait for Home Assistant to restart, then log in to the Home Assistant interface again—this time appending "https://" to the URL. With your server now securely accessible from the Internet, you're allowed to create an IFTTT webhook in "Configuration → Integrations." Head over to IFTTT and build an applet using "Webhooks" either as a trigger or an action, and you can create interactivity between your Home Assistant setup and online tools. What you create, and what you link together, is really up to you. Like many things Home Assistant, you'll need to wade into the documentation to really get your head around it; www.home-assistant.io/docs/ has you covered. Good luck! ⏻

MORE FUNCTIONS



There are plenty of ways to make your home smarter, and a lot your Home Assistant server can do beyond interacting with smart gear. Head to the "Hass.io" tab of the menu, then visit the Add-on Store to check out some of your options. If your server machine has Bluetooth, the Happy Bubbles add-on can detect cheap Bluetooth presence beacons in your home—if you're out, Happy Bubbles can switch everything off, and when you get home, it can switch it on again. There's a Google Assistant SDK add-on, so you can get a Google Assistant node up and running on your Pi, media is well covered, with add-ons for Spotify Connect, Plex, Sonos, AirPlay, and more, and network management is similarly catered for. The same server on which you run Home Assistant can also be home to a Pi-hole ad-blocking instance, a manager for Unifi mesh networks, a Samba share for network file management, and it can generate DNS/DHCP servers to keep all of your network traffic running exactly as you want it. Don't overtax your Raspberry Pi too much, though—while these don't impart huge server overheads, it's best to be a little frugal.

Build Your Own Streaming Stick

YOU'LL NEED THIS

RASPBERRY PI
Any of the main Raspberry Pi models will work.

ANDROID DEVICE
This needs to have the Raspicast app installed.

GOOGLE CHROMECAST is a great way to get media from your smartphone to your TV [**Image A**]. Unfortunately, it's not ideal in some cases. For example, certain routers don't work out of the box with a first-generation Chromecast. Meanwhile, the Chromecast itself is low spec and limited in many ways.

Fortunately, the Raspberry Pi is ready to come to the rescue, providing a Chromecast-like experience when paired with a dedicated mobile app. With a just few terminal commands, you can configure the Raspberry Pi to accept video, music, and audio content streamed from your Android phone or tablet, and dress it up with a slick home screen.

While this should work with any of the main Pi models, we used a Raspberry Pi 3 B+, which delivers fast, stable streaming of HD video from the Android handset. –**CHRISTIAN CAWLEY**

A

1 STREAMING VIDEO, NOT APPS

It's important to emphasize that the Raspberry Pi plus Raspicast setup isn't a complete replacement for the Chromecast. For example, there's no VR support, or Google Home; there's no ambient mode, although it's easy enough to configure a similar home screen, which we'll also look at below.

» In short, media streaming is replicated. Everything else you'll need to add yourself, rely on existing streaming options, or quietly overlook.

2 ENABLE SSH

Start by ensuring the Raspberry Pi is connected to a display, and you have a mouse and keyboard attached. If this isn't possible, you'll need to set this up remotely, controlling your Raspberry Pi over SSH.

» To do this, you need to activate SSH on the Raspberry Pi. If this isn't already enabled, you have two options. The first is to connect a keyboard, open the Raspberry Pi Configuration tool in the "Preferences" submenu on the desktop, click "Interfaces," select "SSH," and click "OK." A reboot may be required.

» The second option is to insert your powered-down Raspberry Pi's microSD card into your computer, browse to the "/boot/" directory, and create an empty text file called "ssh," with no file extension. Eject the card, replace in the Raspberry Pi, and reboot; SSH will be enabled, ready for remote access. Note that you need to know your Raspberry Pi's hostname or IP address for SSH access. You'll find the hostname by entering that word as a command. To see the IP address, either check your router's admin screen or enter `ifconfig`. Look for an entry for "eth0" (Ethernet) or "wifi0" (wireless), and you'll find the IP address labeled "inet."

3 FRUIT UPGRADE

It's time to update your Raspberry Pi. We're assuming you're using the latest version of Raspbian Stretch for this, although other Pi distros should work fine. Open the terminal (or connect via SSH) and enter:

```
sudo apt-get update
sudo apt-get upgrade
```

» With your Pi's repositories refreshed and any upgrades downloaded, it's time to install some prerequisite packages:

```
sudo apt-get install libjpeg9-dev libpng12-dev
```

» Two graphics-based packages are installed here: libjpeg9-dev and libpng12-dev. These enable JPEG and PNG images to be streamed from your Android device to your Raspberry Pi, and displayed on your TV.

4 STREAMING TO THE (OPEN)MAX

Also required is OpenMax, described by its developer as "a GPU accelerated image viewer for the Raspberry Pi." It also includes graphics libraries for GIF and BMP images. Get OpenMax by cloning the GitHub directory:

```
git clone https://github.com/HaarigerHarald/omxiv
```

» Once downloaded, change directory:

```
cd omxiv
```

» Now use the "make" command to build the software:

```
make ilclient
make
```

» You need to wait a while for this to complete. This is a good time to install the Raspicast mobile app, as per the boxout (above-right).

» Once the tool is ready to install, use:

```
sudo make install
```

» Wait while this completes before proceeding. With everything ready to roll on your computer, and the Raspicast app installed on your phone or tablet, it's almost time to start casting. First, open the app and tap the menu to find the SSH settings. Here, input the

INSTALLING RASPICAST

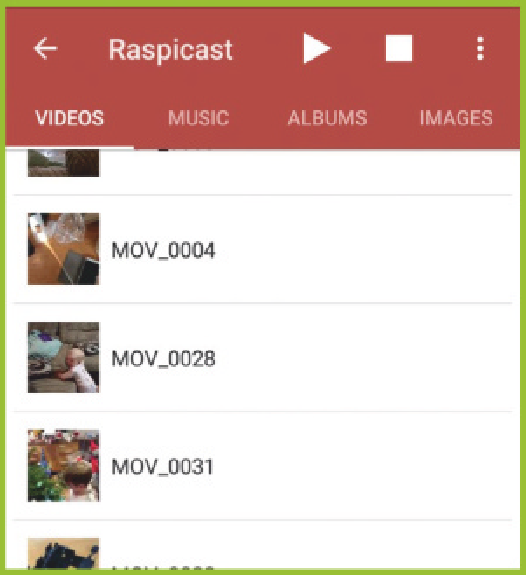
To cast to your Raspberry Pi from your Android phone or tablet (a reliable iPhone or iPad alternative has yet to be released), you need Raspicast, from the Google Play store. Once installed (with all permissions granted), ensure your phone or tablet and the Raspberry Pi are connected to the same network. You can't use Raspicast to stream media from your mobile device to a Raspberry Pi otherwise.

Within the app, you'll find standard controls (play/pause and stop), a file browser, a "Cast" button, and some options that change how Raspicast streams your content.

For example, should you want to replay the current file, open the menu and check the "Repeat" box. Meanwhile, tap "Audio output" to ensure audio is streamed in the correct way. For video, this is typically via the HDMI option, but you might prefer the sound to play on your Android device (local) or even through both. You can also use the ALSA option to pipe the file's audio through the Pi's TRRS A/V port.

Several advanced tools can also be found. Use the "Advanced options" screen to configure these, which include the ability to change the video quality of a YouTube video (switch between HD, SD, and even audio only).

You can also use this screen to change the Raspicast app's theme, set a playlist directory, configure the appearance of subtitles, and even tweak the delay on slideshow images.



hostname or IP address of your Raspberry Pi. You also need to add the username and password. Click "OK" and prepare to start streaming media from your phone.

›› Two options are available: streaming content stored on your phone or tablet from within the app, or by sharing the content from another app. To stream from Raspicast, tap the "Cast" button, and browse the media on your phone. Select the one you want to view, tap the "Play" button, and your Raspberry Pi displays the content on your TV.

›› For sharing (perhaps from YouTube), simply cue a video or song, tap the "Share" button, and select "Raspicast." You'll spot two options: one to play immediately, and one to queue the clip to play later.

›› As versatile as ever, the Raspberry Pi makes a great Chromecast replacement. Raspicast isn't the only method to achieve this, however. If you have Kodi installed on your Raspberry Pi, several remote apps for the media center—including the official option, Kore—offer casting from your mobile device. This is useful, because Raspicast doesn't work on Raspberry Pi-based Kodi systems.

TAKE ME HOME

You might have a Raspberry Pi that receives media, Chromecast-style, from your Android device, but it doesn't quite look the part. Chromecast has a slideshow of curated images for you to enjoy, for example, along with weather, and date and time information. If you want to make your Pi more like Chromecast, you need a kiosk app—one that enables custom images to be displayed as a slideshow. Many of these are available, but the simplest to set up is Andrew Delph's Python slideshow with time and weather, which is on GitHub.

›› Get started by adjusting the Raspberry Pi's video memory. Open the configuration tool with:

```
sudo raspi-config
```

›› Next, browse to "Advanced Options → Memory Split." Here, change the value to 256. This ensures that the Pi's GPU has enough memory available to handle the slideshow images.

›› Click "OK" to continue, then follow the instruction to reboot. Upon restarting, open a new terminal window, and clone the slideshow files from GitHub:

```
git clone https://github.com/andrewdelph/python-slideshow-with-time-and-weather.git
```

›› Once this is downloaded, rename the directory to a snappier title, such as "pyss," with the `mv` command:

```
sudo mv python-slideshow-with-time-and-weather pyss
```

›› You also need the "pyowm" tool. This is a wrapper for the OpenWeatherMap, which brings the necessary weather data on to your Raspberry Pi's desktop:

```
pip install pyowm
```

›› Some additional configuration is required to get this to work. First, you need to remove some images. Open the "pyss" directory first, and remove the four JPEG files starting "WIN_20160220."

›› Next, edit the "ss.py" file:

```
sudo nano ss.py
```

›› Here, look for the line that reads:

```
observation = owm.weather_at_place('Ottawa,CA')
```

›› Change the city and country to match your own location. For example, a New Yorker might use:

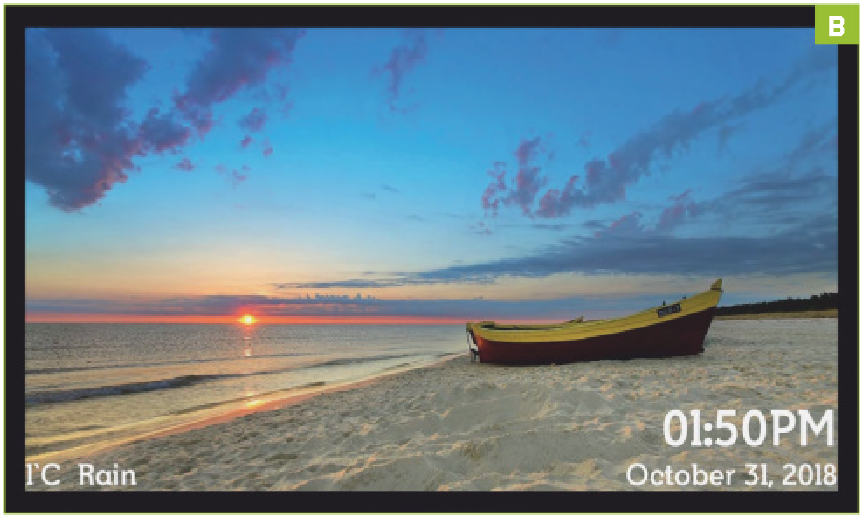
```
observation = owm.weather_at_place('New York,US')
```

›› Press Ctrl-X to save and exit. In the terminal, launch the slideshow:

```
python ss.py
```

›› A gallery of stunning images, the date and time, and current weather [**Image B**] are now displayed on your Raspberry Pi Chromecast replacement! ⏻

B



Set Up a Home Security System

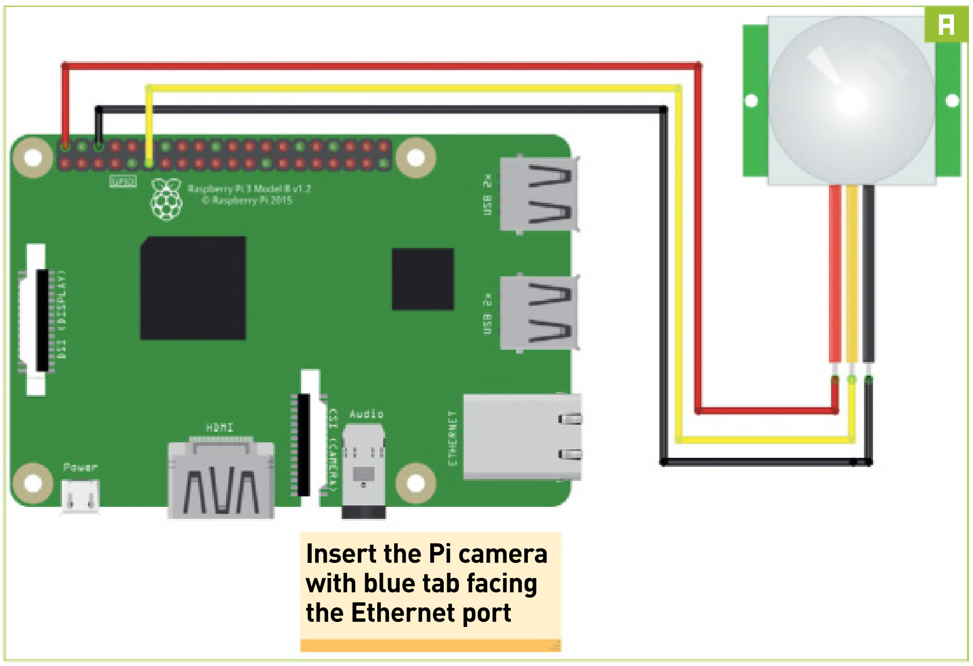
YOU'LL NEED THIS

RASPBERRY PI
Any Pi will do, as long as it has the latest version of Raspbian.

SECURITY HARDWARE
PIR sensor, 3x female-to-female jumper wires, official Pi camera.

PUSHOVER IS A CLEVER notification service for all devices—along with the humble Raspberry Pi—that we're going to use to create an intrusion system that can detect movement using an infrared sensor, and take a picture of the intruder using the official Raspberry Pi camera. This is then sent to all of our devices using the Pushover software.

Our first step in building the hardware is to connect the official camera to the Camera port, located between the HDMI and Ethernet ports (Pi Zero W users, your camera connection is on the edge of the board). With the Raspberry Pi turned off, gently lift the tabs until the port is open, then insert the ribbon cable of the camera so the blue section is facing the Ethernet port. Finally, push the tabs down to lock the cable in place. **–LES POUNDER**



Insert the Pi camera with blue tab facing the Ethernet port

1

CAMERA CHECK

Now boot up your Pi and, from the desktop, go to "Preferences → Raspberry Pi Configuration." Click the "Interfaces" tab and ensure your camera is enabled. You are asked to reboot, so do so, and return to the desktop.

» To check that the camera works, open a terminal and type the following:

```
$ raspistill -o test.jpg
```

» You will see the screen come alive with a live video feed, then after five seconds, it takes a photo. You can view the photo in your "Home" directory.

2

CONNECT THE PIR

Our PIR (passive infrared) sensor has only three pins: VCC, OUT, and GND. These connect to the Raspberry Pi GPIO as follows:

- VCC to 5V GPIO pin
- OUT to GPIO17
- GND to any GND GPIO pin

» With the correct connections made, your security hardware build is now complete [**Image A**].

3

YOU'RE A PUSHOVER

Pushover is a simple notification system that works extremely well, but there's a cost of around $5 per platform, for lifetime access. Of course, you can try out Pushover before you buy, and there's a seven-day trial period. For this project, we purchased a license for desktop and our Android device. Head over to https://pushover.net, sign up for a new account [**Image B**], and download the app from the Google Play store.

» After setting up the account, create an application called "Alarm," enter the description, then check the box before clicking "Create Application." When the application is created, you'll see an API/Token Key. Copy this and keep it safe. Don't share it with anyone or post it online. This code enables the app to send messages, and is unique to you. On the main Pushover page, there is a User Key. Again, note this down and keep it safe.

» For this project, we are writing Python code using the Python 3 editor, found in the "Programming" menu. Click "File → New," then in the new window, click "File → Save," and call the file "Alarm.py."

» We start the code by importing some libraries. The first is "requests," used to work with HTTP requests. Then we import "datetime" to get time and date data for our alarm system. From four further libraries we import the PIR sensor class from "gpiozero," the "PiCamera" class from "picamera," and "pause" from "signal," which is used to stop our code exiting. Finally, we import the "sleep" function from "time," to introduce a delay:

```
import requests, datetime
from gpiozero import MotionSensor
from picamera import PiCamera
from signal import pause
from time import sleep
```

4

PERFECT PIR

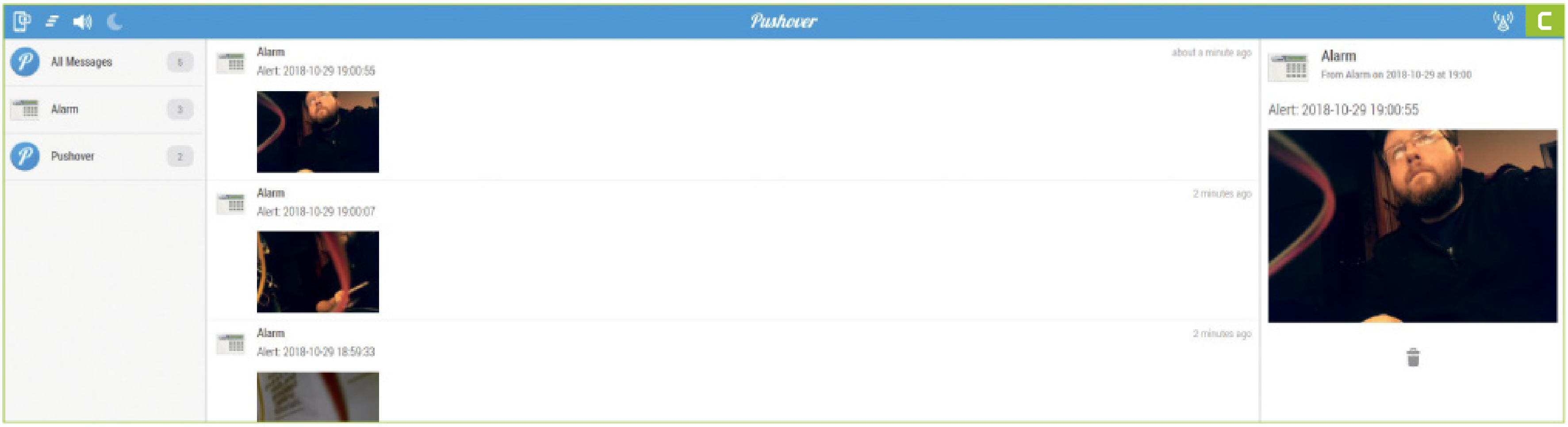
Next we create two objects—one to enable easy use of the camera library; the other tells our code where the PIR sensor is connected:

```
camera = PiCamera()
pir = MotionSensor(17)
```

» In order for the PIR sensor to "settle" and reduce the amount of false triggers, we pause the startup for 10 seconds, and inform the user that the system is now armed and ready to use:

```
print("ALARM Starting")
sleep(10)
```

» The sequence to detect movement and trigger the image capture and posting to Pushover is all contained



Alarm
Alert: 2018-10-29 19:00:55
about a minute ago

Alarm
Alert: 2018-10-29 19:00:07
2 minutes ago

Alarm
Alert: 2018-10-29 18:59:33
2 minutes ago

Alarm
From Alarm on 2018-10-29 at 19:00

Alert: 2018-10-29 19:00:55

C

in a function called "send_msg." This function gets the time and date of the intrusion, and stores it to a variable called "timestamp," where we then use string formatting to convert the information into Year, Month, Day, Hour, Minutes, and Seconds:

```
def send_msg():
    timestamp = datetime.datetime.now()
    timestamp = str(timestamp.strftime("%Y-%m-%d
%H:%M:%S"))
```

5 INTRUDER ALERT!

We print that the alarm has been triggered, along with the time of the intrusion, before we use the "camera.capture" function to take a picture, and use the timestamp as the filename followed by ".jpg":

```
    print("ALARM TRIGGERED: "+timestamp)
    camera.capture("/home/pi/"+str(timestamp)+".jpg")
```

›› In order to post the alert to Pushover, we need to use requests to post the alert to a specific URL in a JSON format. We then pass our token and user keys inside a dictionary, along with a message that tells the reader that an alert has been triggered, with the time/date of the intrusion:

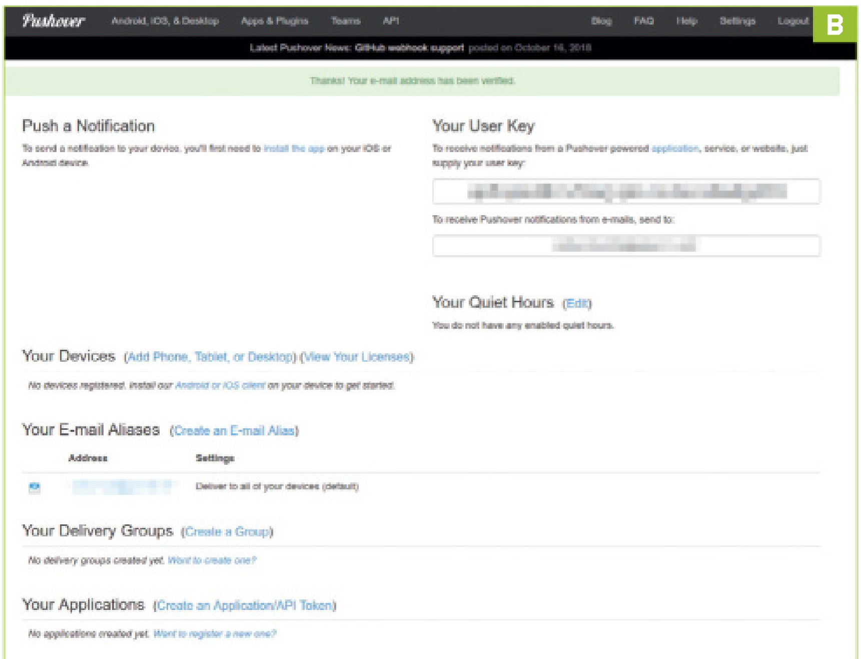
```
    r = requests.post("https://api.pushover.net/1/messages.json",
 data = {
        "token": "API TOKEN",
        "user": "API USER KEY",
        "message": ("Alert: "+timestamp)
    },
```

›› The next step for Pushover is to send the image across, and for this we use another dictionary to contain the "attachment," which is used to open the timestamp file as read-only. We also need to tell the code that the file is a JPEG image. Then we print the response of all the actions, handily contained in the "r" object we created for our request. This prints in the shell, and gives us an indication that the code is working. Finally, we sleep for 30 seconds to enable the PIR to settle, although you can change this delay to meet your own particular requirements. This is the last part of the function:

```
    files = {
      "attachment": (timestamp, open("/home/
pi/"+timestamp+".jpg", "rb"), "image/jpeg")
    }
    print(r.text)
    sleep(30)
```

›› The last two lines of code start with our PIR sensor sensing motion, then calling the function we've created. Then we use `pause()` to prevent the code from exiting, effectively running the code until the next intrusion is detected. You can find all the code at https://github.com/lesp/LXF245-AlarmSystem/archive/master.zip.

›› Save the code, and click "Run → Run Module" to start. Now run around and keep an eye on your Android device, because Pushover will ping messages to your phone, showing pictures of you [**Image C**]. Finally, install the unit somewhere safe in a small box, and capture those intruders on camera! ⏻



B

Latest Pushover News: GitHub webhook support posted on October 16, 2018

Thanks! Your e-mail address has been verified.

Push a Notification

To send a notification to your device, you'll first need to install the app on your iOS or Android device.

Your User Key

To receive notifications from a Pushover powered application, service, or website, just supply your user key:

[redacted]

To receive Pushover notifications from e-mails, send to:

[redacted]

Your Quiet Hours (Edit)

You do not have any enabled quiet hours.

Your Devices (Add Phone, Tablet, or Desktop) (View Your Licenses)

No devices registered. Install our Android or iOS client on your device to get started.

Your E-mail Aliases (Create an E-mail Alias)

Address	Settings
[redacted]	Deliver to all of your devices (default)

Your Delivery Groups (Create a Group)

No delivery groups created yet. Want to create one?

Your Applications (Create an Application/API Token)

No applications created yet. Want to register a new one?

PULL ME, PUSH ME

In this project, we created our own Pushover application that sends alerts to a waiting Android app, but there are other ways to interact with Pushover. There are apps for Android, iOS, Chrome, Firefox, and Safari. We tested the Chrome application, which can be installed from https://pushover.net/clients, and it worked flawlessly.

There's also a dedicated system tray application that works pretty well with Pushover. The unofficial Pullover application is useful for receiving the alerts from our device, but sadly it can't display images. That said, the app is handy for receiving text alerts—for example, remote sensor triggers, such as temperature, pressure, and light levels. Pullover can be found at https://github.com/cgrossde/Pullover, and it works with Linux, Mac, and Windows devices.

Pushover has an extensive API (application programming interface) that enables us to create groups to receive messages, but it can also work with third-party applications, such as IFTTT (If This Then That), the Internet of Things gateway that enables visual programming of triggers or events that cause interesting outcomes—for example, geofencing a supermarket to prompt your device to show your shopping list!

Create an Animated GIF from Any Video

YOU'LL NEED THIS

A VIDEO
If you don't have your own video to convert to a GIF, we explain how to source one below.

SHOTCUT
Download this free app from www.shotcut.org.

THEY SAY A PICTURE is worth a thousand words, but an animated GIF is worth a million. Despite the rise of HTML5 video, these little animations are still hugely popular—partly because of their relatively small file size, which is friendly to mobile devices on limited data plans, and also because the format is so widely supported.

Sites such as Giphy (https://giphy.com) are a great source of ready-made animations, but sometimes you can only express yourself by creating your own—and with the right tools, it's surprisingly easy to do.

If you already have a video file, skip straight to Step 5 to find out how to edit and convert it. Alternatively, you can grab and convert a video from YouTube, as explained in Step 1, or make a recording from your desktop, as described in Step 3. This is a great way to make a GIF from a game or movie playing on your PC. –CAT ELLIS

1

FIND A VIDEO ONLINE

If you have the copyright holder's permission, or you uploaded it yourself, you can download a video from the web to turn into a GIF. Download and install 4K Video Downloader (www.4kdownload.com), then find the video you want online, and copy its address from your web browser. Open 4K Video Downloader and click the green "Paste link" button [**Image A**].

2

SAVE IT TO YOUR PC

You're now prompted to choose a quality option. Part of the appeal of animated GIFs is their small size, so the "High quality 480p" option is fine. Leave the format as MP4, choose a location for the saved file—we recommend either your desktop or your "Videos" directory—and click "Download." You'll see a green progress bar; once this is full, your video is ready for you to use.

3

CAPTURE A VIDEO FROM YOUR SCREEN

If you want to make a GIF from a game or other software, you need free screen recorder OBS Studio. It might look intimidating at first, but it's remarkably easy to use. Download it from https://obsproject.com/download, and run the installer. You don't need the plugins, so feel free to uncheck them. When it's done, launch the software, and skip the optimization wizard [**Image B**].

4

START AND STOP RECORDING

Click the "+" icon under "Sources," and select "Display capture" from the drop-down menu [**Image C**]. Click the "Start recording" button on the right, then minimize OBS Studio, and do whatever you want to record. When you've finished, maximize the recorder, and click "Stop recording." The captured footage is saved automatically in FLV format, and stored in your "Videos" directory.

5

DOWNLOAD SHOTCUT

Whether you've downloaded a video, recorded your own, or found one somewhere else, Shotcut is the best tool for converting it to GIF format. It's totally free, doesn't add watermarks to your videos, and is packed with lots of handy tools and filters to make your GIFs look great. Download it from www.shotcut.org, and run the installer. When it's done, click "Close," and launch the program.

6

CROP YOUR VIDEO

Click "Open file" and load your chosen video. GIFs work best if they're tightly cropped to focus on the most important part of the action. If your video needs cropping, click "Filters," then the "+" icon to add a new filter. Click the small monitor icon to see video filters, then click "Crop." Use the sliders to adjust how much is cut off the top, bottom, and sides of the video [**Image D**].

7

KEEP IT BRIEF

Drag the video preview into the timeline at the bottom. Try to make your GIF 10 seconds long or shorter. Drag the vertical white bar (the playhead) along the waveform until you find the point where you want your GIF to start, and click "Split at playhead" [**Image E**]. Select the section of video you want to remove and tap Delete. Now do the same for the end of the video.

8

PREPARE TO EXPORT

When you've trimmed your video, click "Export," and select "GIF" as the format. Now look at the resolution. The ideal size depends on where you're planning to use it, but 800x600 should be fine for most purposes [**Image F**]. Click the "Codec" tab, and change the codec to "GIF"—you need to scroll down to find it.

9

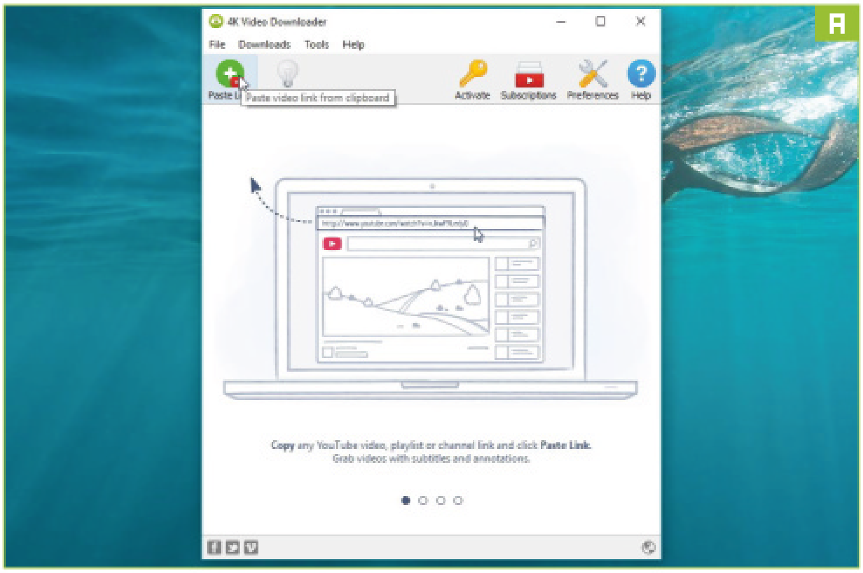
SAVE YOUR GIF

GIF format doesn't support sound, so click "Audio" and select "Disable audio." Reduce the frame rate to approximately 15fps, click "Export file," give it a name ending in the extension ".gif," and click "Save" [**Image G**]. A status bar on the right shows you when it's finished processing. Congratulations, you've turned a video into an animated GIF, ready to share wherever you like.

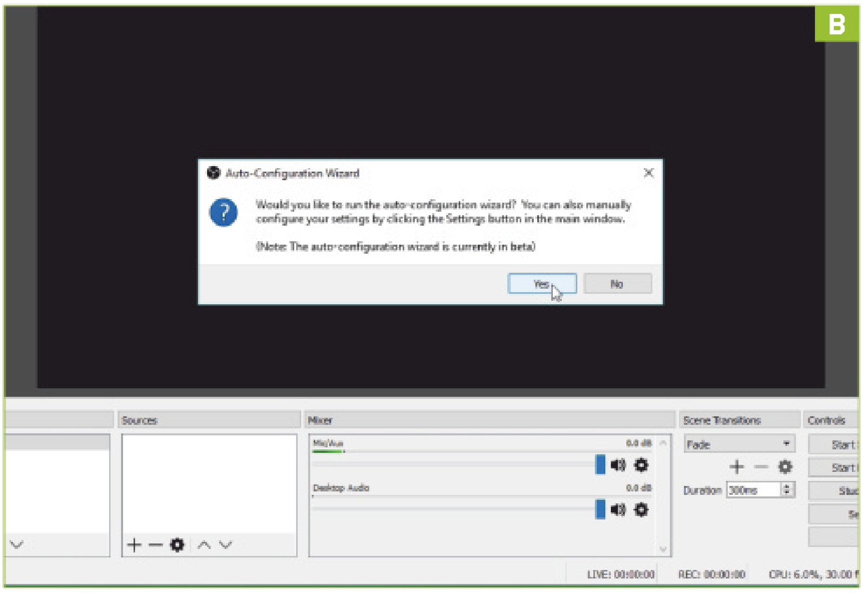
10

GET THE SIZE RIGHT

Want to share your GIF on a certain site, but not sure about the best size? Sprout Social has a handy guide at http://bit.ly/2Gb2QR7 that shows the optimum image dimensions for popular social networks, including Twitter, Facebook, and Pinterest [**Image H**]. It's a very useful reference that will help ensure your GIFs look as good as possible when you publish them.


A
4K Video Downloader
File Downloads Tools Help
Paste Link
Paste video link from clipboard
Activate Subscriptions Preferences Help

Copy any YouTube video, playlist or channel link and click Paste Link.
Grab videos with subtitles and annotations.


B
Sources
Mixer
Scene Transitions
Controls
Mic/Aux
Desktop Audio
Fade
Yes
No

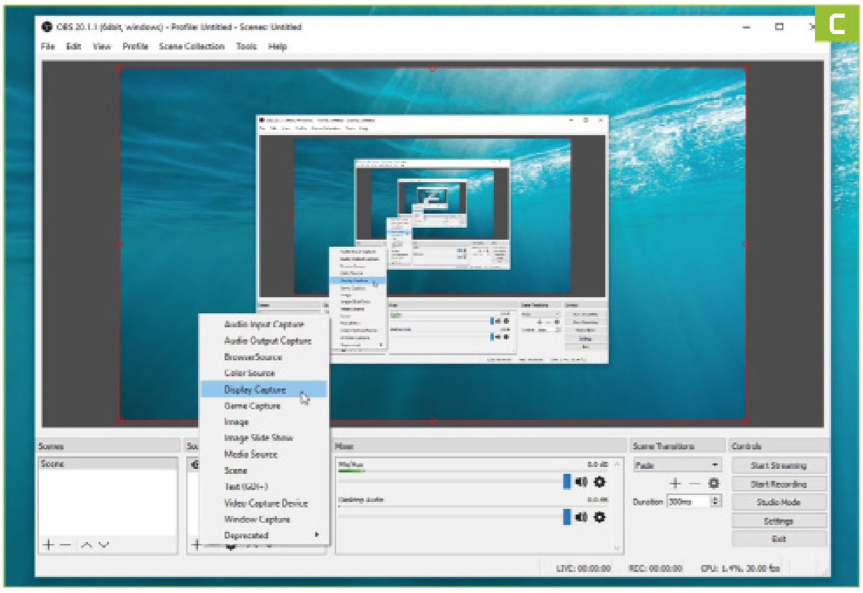
Auto-Configuration Wizard

Would you like to run the auto-configuration wizard? You can also manually configure your settings by clicking the Settings button in the main window.

(Note: The auto-configuration wizard is currently in beta)

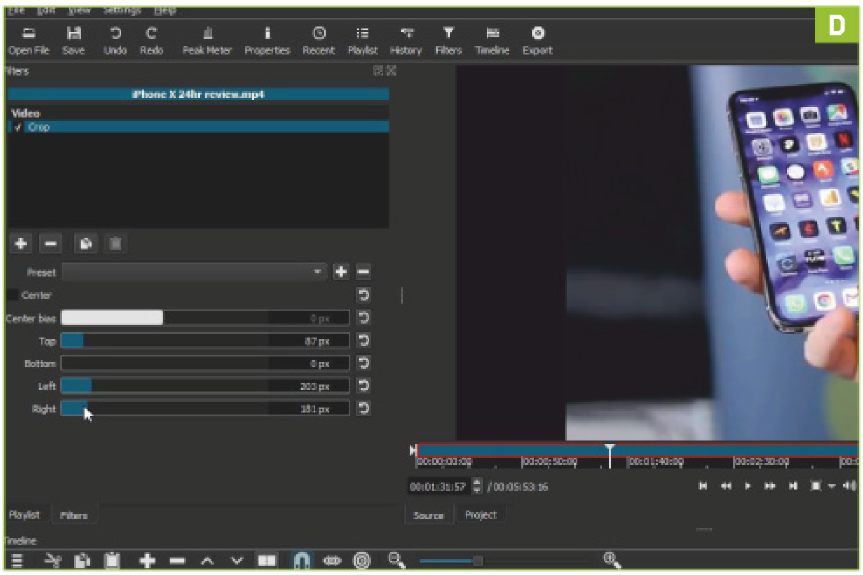
Duration 300ms

LIVE: 00:00:00 REC: 00:00:00 CPU: 6.0%, 30.00 fps


C
File Edit View Profile Scene Collection Tools Help
Audio Input Capture
Audio Output Capture
BrowserSource
Color Source
Display Capture
Game Capture
Image
Image Slide Show
Media Source
Scene
Text (GDI+)
Video Capture Device
Window Capture
Deprecated
Scenes
Scene
Mixer
Scene Transitions
Controls
Start Streaming
Start Recording
Studio Mode
Settings
Exit

OBS 20.1.1 (64bit, windows) - Profile: Untitled - Scenes: Untitled

LIVE: 00:00:00 REC: 00:00:00 CPU: 1.4%, 30.00 fps


D
Open File Save Undo Redo Peak Meter Properties Recent Playlist History Filters Timeline Export
Filters
Video
Crop
Preset
Playlist Filters
Source Project
Timeline

iPhone X 24hr review.mp4

Center bias 0 px

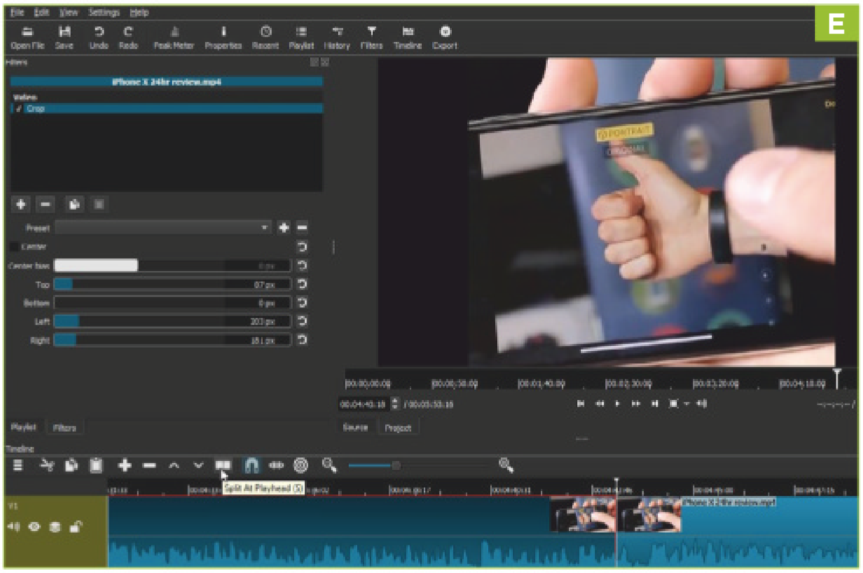
Top 87 px

Bottom 0 px

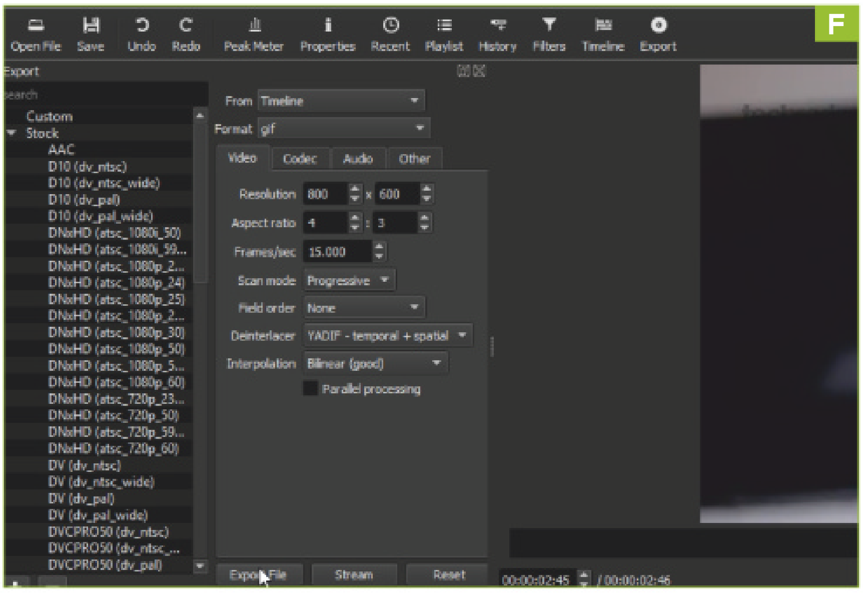
Left 203 px

Right 181 px

00:01:31:57 / 00:05:53:16


E
File Edit View Settings Help
Open File Save Undo Redo Peak Meter Properties Recent Playlist History Filters Timeline Export
Filters
Video
Crop
Preset
Center
Center bias
Top
Bottom
Left
Right
Playlist Filters
Source Project
Timeline
Split At Playhead (S)
V1

iPhone X 24hr review.mp4


F
Open File Save Undo Redo Peak Meter Properties Recent Playlist History Filters Timeline Export
Export
Search
Custom
Stock
AAC
D10 (dv_ntsc)
D10 (dv_ntsc_wide)
D10 (dv_pal)
D10 (dv_pal_wide)
DNxHD (atsc_1080i_50)
DNxHD (atsc_1080i_59...
DNxHD (atsc_1080p_2...
DNxHD (atsc_1080p_24)
DNxHD (atsc_1080p_25)
DNxHD (atsc_1080p_2...
DNxHD (atsc_1080p_30)
DNxHD (atsc_1080p_50)
DNxHD (atsc_1080p_5...
DNxHD (atsc_1080p_60)
DNxHD (atsc_720p_23...
DNxHD (atsc_720p_50)
DNxHD (atsc_720p_59...
DNxHD (atsc_720p_60)
DV (dv_ntsc)
DV (dv_ntsc_wide)
DV (dv_pal)
DV (dv_pal_wide)
DVCPRO50 (dv_ntsc)
DVCPRO50 (dv_ntsc_...
DVCPRO50 (dv_pal)
Video Codec Audio Other
Export File
Stream
Reset

From Timeline

Format gif

Resolution 800 x 600

Aspect ratio 4 : 3

Frames/sec 15.000

Scan mode Progressive

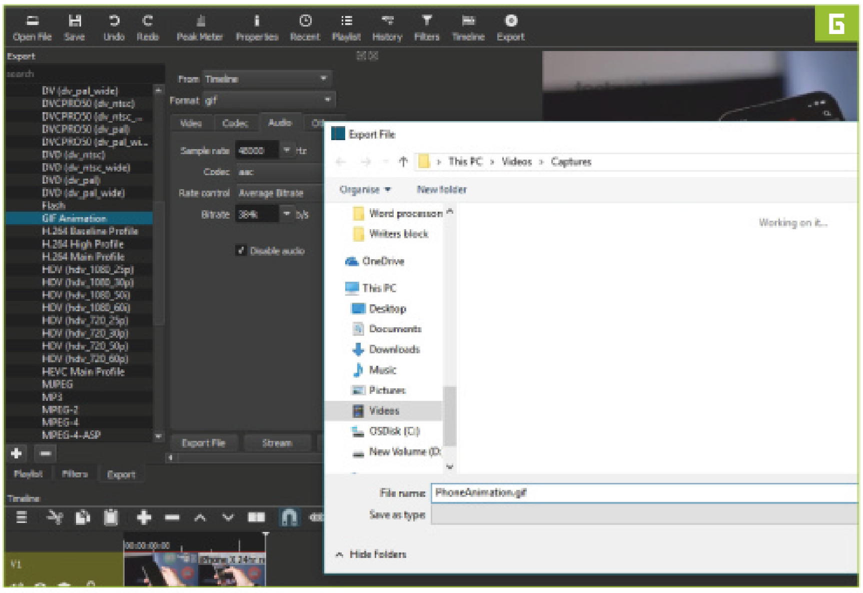
Field order None

Deinterlacer YADIF - temporal + spatial

Interpolation Bilinear (good)

☐ Parallel processing

00:00:02:45 / 00:00:02:46


G
Open File Save Undo Redo Peak Meter Properties Recent Playlist History Filters Timeline Export
Export
search
DV (dv_pal_wide)
DVCPRO50 (dv_ntsc)
DVCPRO50 (dv_ntsc_...
DVCPRO50 (dv_pal)
DVCPRO50 (dv_pal_wi...
DVD (dv_ntsc)
DVD (dv_ntsc_wide)
DVD (dv_pal)
DVD (dv_pal_wide)
Flash
GIF Animation
H.264 Baseline Profile
H.264 High Profile
H.264 Main Profile
HDV (hdv_1080_25p)
HDV (hdv_1080_30p)
HDV (hdv_1080_50i)
HDV (hdv_1080_60i)
HDV (hdv_720_25p)
HDV (hdv_720_30p)
HDV (hdv_720_50p)
HDV (hdv_720_60p)
HEVC Main Profile
MJPEG
MP3
MPEG-2
MPEG-4
MPEG-4-ASP
Video Codec Audio
Export File Stream
Playlist Filters Export
Timeline
V1
Export File
This PC › Videos › Captures
Organise New folder
Word processors
Writers block
OneDrive
This PC
Desktop
Documents
Downloads
Music
Pictures
Videos
OSDisk (C:)
New Volume (D:
Working on it...
Hide Folders

From Timeline

Format gif

Sample rate 48000 Hz

Codec aac

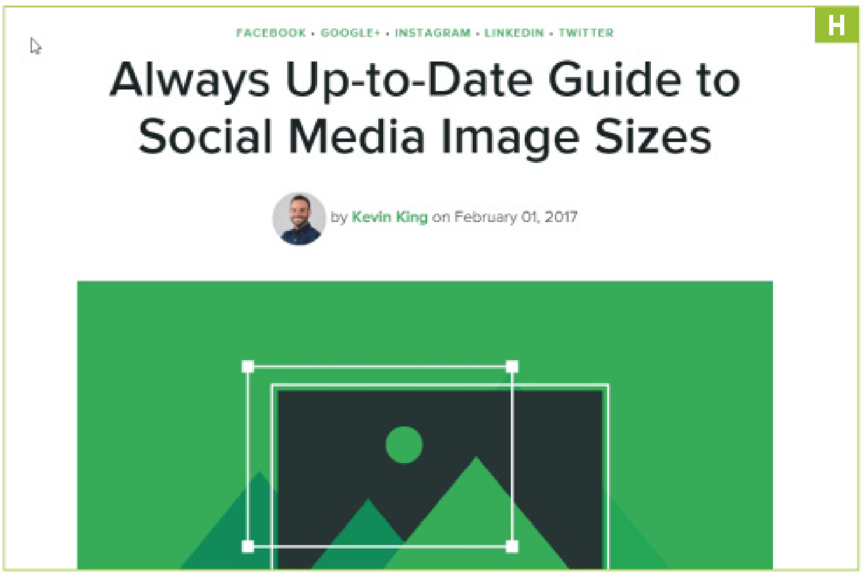
Rate control Average Bitrate

Bitrate 384k b/s

☑ Disable audio

File name: PhoneAnimation.gif

Save as type:



FACEBOOK • GOOGLE+ • INSTAGRAM • LINKEDIN • TWITTER

Always Up-to-Date Guide to Social Media Image Sizes

by Kevin King on February 01, 2017

Run Your Own Plex Media Server

YOU'LL NEED THIS

A PC OR NAS DRIVE
Along with a collection of media that you want to play on your devices.

WHO DOESN'T LOVE A GOOD MOVIE, or enjoy relaxing by kicking back listening to music? Many people have a huge media collection sitting on their computer, and knowing how to keep this organized—and how best to access it—is a problem that you've probably encountered. One of the best tools for the job is Plex. This incredible piece of software can be used to catalog your entire media collection, make it easier to navigate and play back, and gives you the ability to stream your music and movies to all of your devices.

Plex can be used in a couple of ways, and at its heart is its server component. Don't let the word "server" put you off; the Plex server is simply software that you install on your PC—or on a NAS drive—and point at your media files, ready for playback from other connected devices. Read on to find out more. –**MARK WYCIŚLIK-WILSON**

1 CREATE A PLEX ACCOUNT

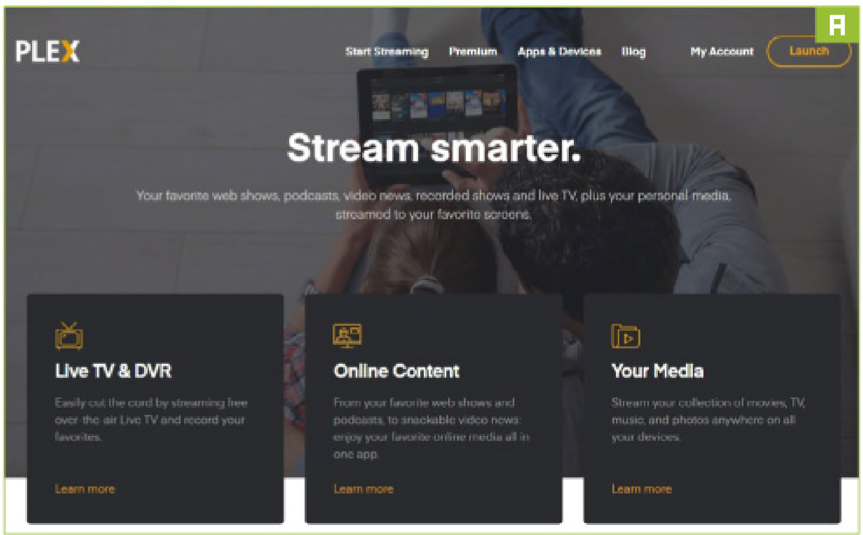
First, point your web browser at www.plex.tv [**Image A**], and click the "Sign Up" button at the upper-right of the page. You can use a Google account, your Facebook credentials, or an email address to set up a new account. If you opt to use your email address, you're prompted to create a password—otherwise, you just have to provide your Facebook or Google details.

2 DOWNLOAD PLEX MEDIA SERVER

Next you need to install the Plex software on the PC or device that you intend to use as your media server. You should automatically be taken to a page linking to the Plex Media Server download, but if you aren't, go to https://app.plex.tv/desktop. If you are installing the software on a network drive, you need to click the "Download for NAS Platforms" link, otherwise click "Download for Computer Platforms."

3 INSTALL THE SERVER SOFTWARE

With Plex Media Server downloaded, you now need to install it. You don't need to be concerned about changing any settings; just run through the installation, clicking "Yes" if a User Account Control dialog appears. Once the installation is complete—it shouldn't take very long—click the "Launch" button, and you're ready to start configuring your Plex server.


A
PLEX
Start Streaming
Premium
Apps & Devices
Blog
My Account
Launch
Learn more
Learn more
Learn more

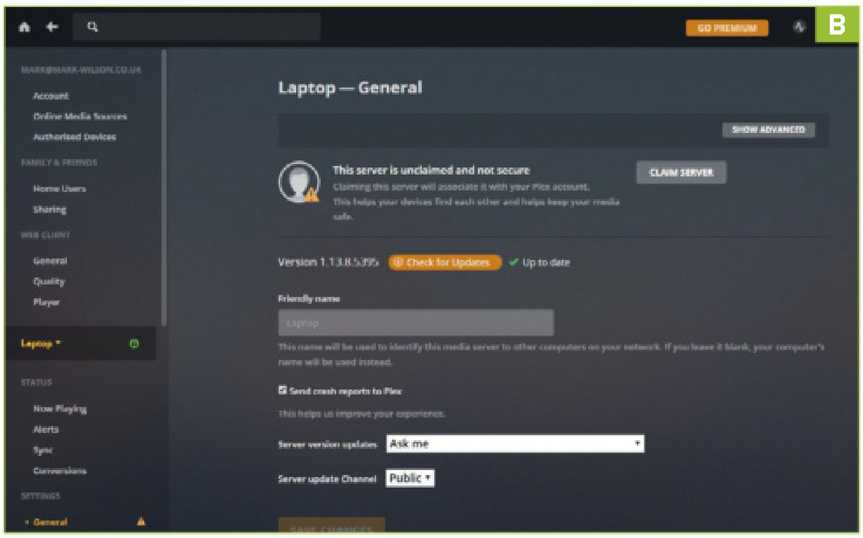
Stream smarter.

Your favorite web shows, podcasts, video news, recorded shows and live TV, plus your personal media, streamed to your favorite screens.

Live TV & DVR
Easily cut the cord by streaming free over the air Live TV and record your favorites.

Online Content
From your favorite web shows and podcasts, to snackable video news: enjoy your favorite online media all in one app.

Your Media
Stream your collection of movies, TV, music, and photos anywhere on all your devices.


B
GO PREMIUM
MARK@MARK-WILSON.CO.UK
Account
Online Media Sources
Authorised Devices
FAMILY & FRIENDS
Home Users
Sharing
WEB CLIENT
General
Quality
Player
Laptop
STATUS
Now Playing
Alerts
Sync
Conversions
SETTINGS
General
SHOW ADVANCED
CLAIM SERVER
Check for Updates
SAVE CHANGES

Laptop — General

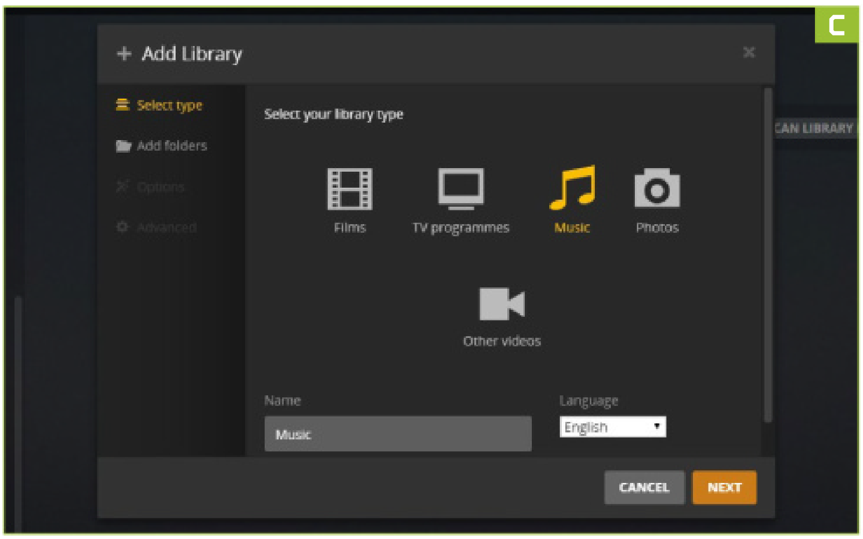
This server is unclaimed and not secure
Claiming this server will associate it with your Plex account. This helps your devices find each other and helps keep your media safe.

Version 1.13.8.5395 ✓ Up to date

Friendly name: Laptop
This name will be used to identify this media server to other computers on your network. If you leave it blank, your computer's name will be used instead.

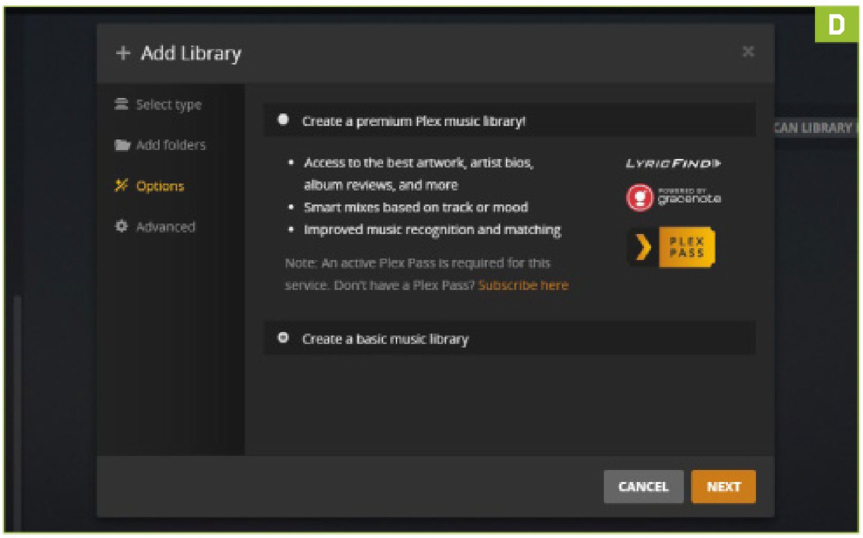
☑ Send crash reports to Plex
This helps us improve your experience.

Server version updates: Ask me
Server update Channel: Public


C
Add Library
Select type
Add folders
Options
Advanced
SCAN LIBRARY
Films
TV programmes
Music
Photos
Other videos
CANCEL
NEXT

Select your library type

Name: Music
Language: English


D
Add Library
Select type
Add folders
Options
Advanced
SCAN LIBRARY
LYRICFIND
POWERED BY gracenote
PLEX PASS
CANCEL
NEXT

● Create a premium Plex music library!

- Access to the best artwork, artist bios, album reviews, and more
- Smart mixes based on track or mood
- Improved music recognition and matching

Note: An active Plex Pass is required for this service. Don't have a Plex Pass? Subscribe here

○ Create a basic music library

4 START SERVER CONFIGURATION

A Plex icon should now appear in the notification area of the system tray—either right-click it and select "Open Plex," or double-click it to access Plex Server's web interface. On the web page that loads, you should see a message informing you that an unclaimed server has been detected. Click "Claim it now," followed by the "Claim Server" button [**Image B**] .You can now configure your media.

5 ADD YOUR MEDIA LIBRARIES

In the list of options that appear on the left, scroll down and click "Libraries" followed by "Add Library." Choose the type of media library you'd like to add first (in this case, music), and click the corresponding icon, followed by "Next" [**Image C**]. Click "Browse For Media Folder," then navigate to a folder on your PC containing the relevant media. Click "Add."

6 ADD MORE LIBRARIES AND SCAN FOR MEDIA

If your media is stored in more than one location, click the "Browse For Media Folder" button again to add another folder. When you've added all the necessary folders, click "Next," select "Create a basic music library" (unless you have paid for a Plex subscription) [**Image D**], and click "Next" followed by "Add Library." You can then repeat the process for all your other media files and libraries.

7 BROWSE YOUR LIBRARIES

Now wait while Plex scans the folders you have selected, analyzes the files it finds, and adds tags and labels. If you click the "Home" button in the upper-left corner, you can watch in real time as media files are added to your library. While the library update is underway, you'll notice that the "Activity" icon—the "pulse" icon, upper-right—spins to show you that something is happening [**Image E**].

8 INSTALL PLEX MEDIA PLAYER

There are various ways to access your media collection with Plex, including the browser-based app at https://app.plex.tv, and the desktop version, named Plex Media Player, for Windows and macOS [**Image F**]. To download and install the standalone app for your PC, head to https://www.plex.tv/apps-devices/#modal-devices-plex-media-player, and click the "Get Download" button.

9 PLAY YOUR MEDIA

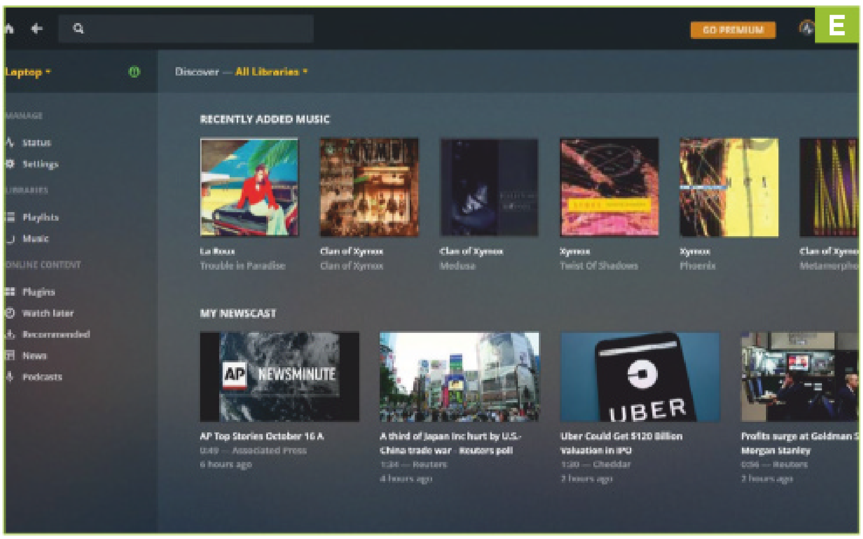
With Plex Media Player installed, fire it up, sign in to your Plex account, and the app searches for available servers. Once your Plex server has been located, use the left-hand navigation bar, or the deck view to the right, to navigate through your media collection, as well as online content [**Image G**]. Controls and navigation are much like any other media player.

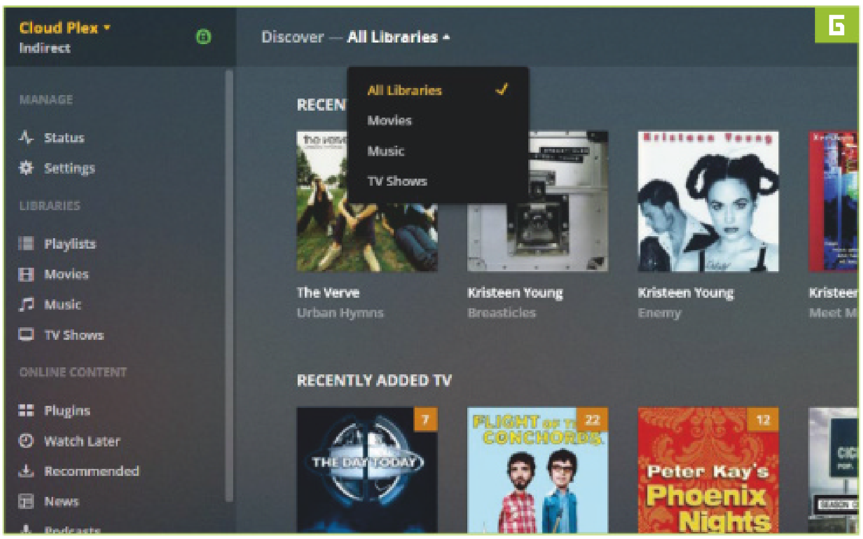
10 INSTALL MOBILE APPS

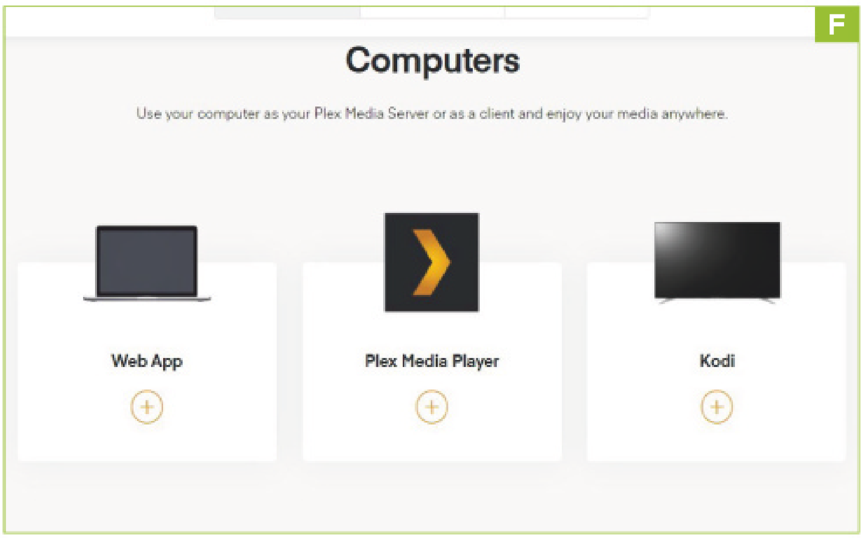
Whether you have an iPhone or Android phone—or an iPad, for that matter—there's a mobile app you can use to enjoy your media collection when you're away from your PC. Just make sure your Plex server is on, and an Internet or data connection is available. The Plex mobile apps can be downloaded for free from the App Store and Google Play [**Image H**]. ⏻

SERVER SUGGESTION

A spare, old, or unused PC is ideal for use as a Plex server. Run it 24/7, and your media will always be available.


E
GO PREMIUM
Laptop
Discover — All Libraries
MANAGE
Status
Settings
LIBRARIES
Playlists
Music
ONLINE CONTENT
Plugins
Watch later
Recommended
News
Podcasts
RECENTLY ADDED MUSIC
MY NEWSCAST
AP NEWSMINUTE
UBER

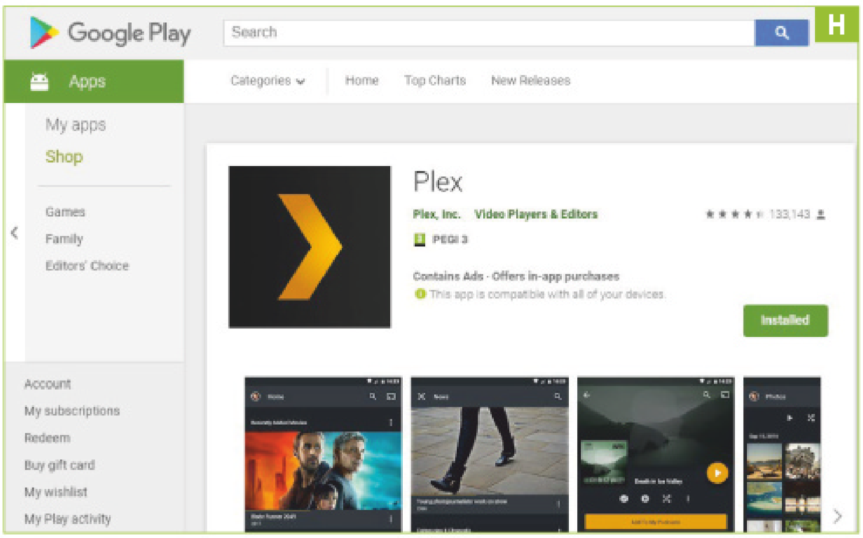

G
Cloud Plex
Indirect
Discover — All Libraries
All Libraries
Movies
Music
TV Shows
MANAGE
Status
Settings
LIBRARIES
Playlists
Movies
Music
TV Shows
ONLINE CONTENT
Plugins
Watch Later
Recommended
News
Podcasts
RECENTLY ADDED TV
The Verve
Urban Hymns
Kristeen Young
Breasticles
Kristeen Young
Enemy
Peter Kay's Phoenix Nights


F

Computers

Use your computer as your Plex Media Server or as a client and enjoy your media anywhere.

Web App
Plex Media Player
Kodi


H
Google Play
Search
Apps
Categories
Home
Top Charts
New Releases
My apps
Shop
Games
Family
Editors' Choice
Account
My subscriptions
Redeem
Buy gift card
My wishlist
My Play activity
Plex
Plex, Inc.
Video Players & Editors
PEGI 3
Contains Ads · Offers in-app purchases
This app is compatible with all of your devices.
Installed

BUILD IT

IAN EVENDEN, CONTRIBUTING EDITOR

The Multicore Upgrade

When you change this much of your machine, is it still the same PC you started out with?

LENGTH OF TIME: **1-3 HOURS**

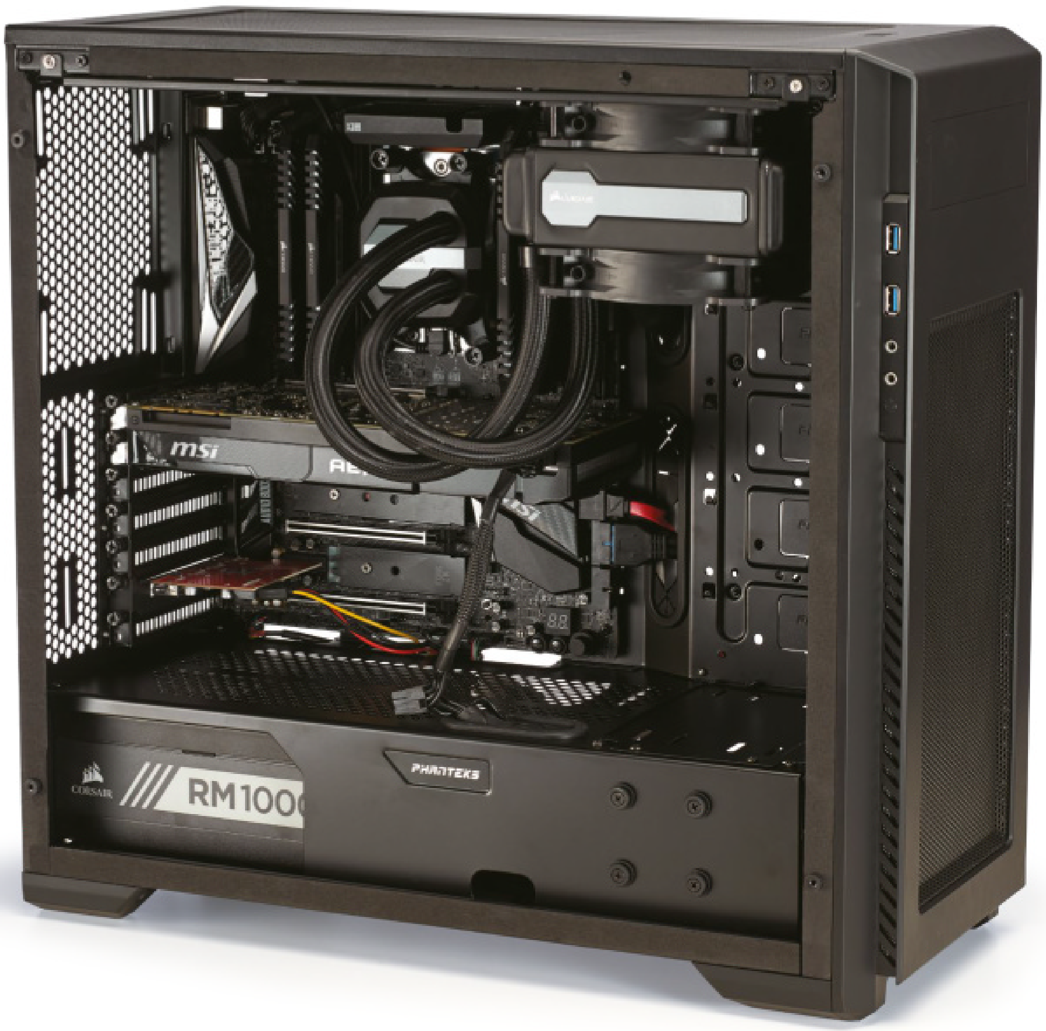
LEVEL OF DIFFICULTY: **MEDIUM**

THE CONCEPT

I DIDN'T NEED A NEW PC, but I wanted one. My old gaming/image-editing build was constructed in 2012, and had grown organically over time. It was based around a Core i7-3770K, and had 32GB of DDR3—absolute overkill, but I didn't foresee the effect cheaper SSDs would have, expecting huge amounts of RAM to become more common instead. Originally, it booted into Windows 8 from a Samsung 840 128GB SSD, with a 500GB WD Velociraptor for storage, plus a DVD drive, and a GeForce GTX 680 to push the pixels. All in a Cooler Master Silencio 450 case, with a Corsair 750W power supply.

A games PC is also a multi-purpose PC, and it handled everything I threw at it for years; my main PC for work and leisure. But the need to fiddle and improve is strong, and as new products hit the market and prices came down, I added to it. Windows 10 came along. The Velociraptor was replaced with a 500GB SSD, then a second one was added, and a 2TB Seagate Barracuda hard drive. The DVD drive went in the cupboard. The Arctic Cooling Freezer 7 Pro cooler gave way to a Zalman closed-loop water cooler, and the GPU became a GTX 970, then a GeForce GTX 1070 Ti. After all this, it was still the same PC.

Replacing the motherboard and CPU, however, changes everything. The itch became so strong, it couldn't be ignored, and in a moment of madness, and with Cyber Monday in full swing, the six-year-old Core i7 was ousted in favor of a Threadripper 2950X, with new a mobo and RAM. Then power supply and case. And some SSDs. The question is, is it still the same PC now?



IN WITH THE NEW, AND THE OLD

AT FIRST, THE 32-CORE 2990WX was considered, just because I like big numbers, but that chip's unique layout means it's extremely fast in the right application, but because the memory bandwidth is rationed out quite thinly, it suffers in many common tasks. The 2950X seemed like a much better bet, with the added bonus of being cheaper. RAM is Corsair, 32GB of the C16 LED DDR4 that lights up white, as it was keenly priced at the time.

Storage comes courtesy of M.2 drives—a Western Digital Blue 2TB SATA model for game downloads, and a 512GB Samsung 970 Evo as the boot drive, plus a 2TB spinner left over from the old build. Power is supplied by Corsair's modular 1,000W unit—this has the benefit of shutting off its fan when not under load, for extra quietness. We turned to Corsair again for CPU cooling, the Hydro Series H80i V2 fitting both the case and the chip, and its quiet fan and pump profiles help, too. The soundproofing on the Silencio case should add to this for a reasonably quiet build.

This PC is going to use a lot of USB devices, so I added an Icy Box 873 in one of the 5.25-inch bays, bringing with it a USB 3 reader for CompactFlash cards, as well as a couple more USB ports, including some type Cs, and a high-speed charging port.

The old case doesn't come with a window, so there's little point in glowing components. The MSI Aero 1070 Ti graphics card is plain black, but the MSI X399 Gaming Pro motherboard and the Corsair RAM do have lighting—we'll just turn it off.

INGREDIENTS

PART		STREET PRICE
CPU	AMD Threadripper 2950X	**$900**
Motherboard	MSI X399 Gaming Pro Carbon	**$390**
RAM	Corsair Vengeance LED DDR4 RAM (4x 8GB)	**$480**
PSU	Corsair RM1000x PSU	**$170**
Cooler	Corsair Hydro H80i V2	**$100**
Storage 1	512GB 970 Evo	**$300**
Storage 2	2TB WD Blue SSD	**$400**
Case	Phanteks Enthoo Pro M	**$100**
Total		**$2,840**

1

PSU WOES

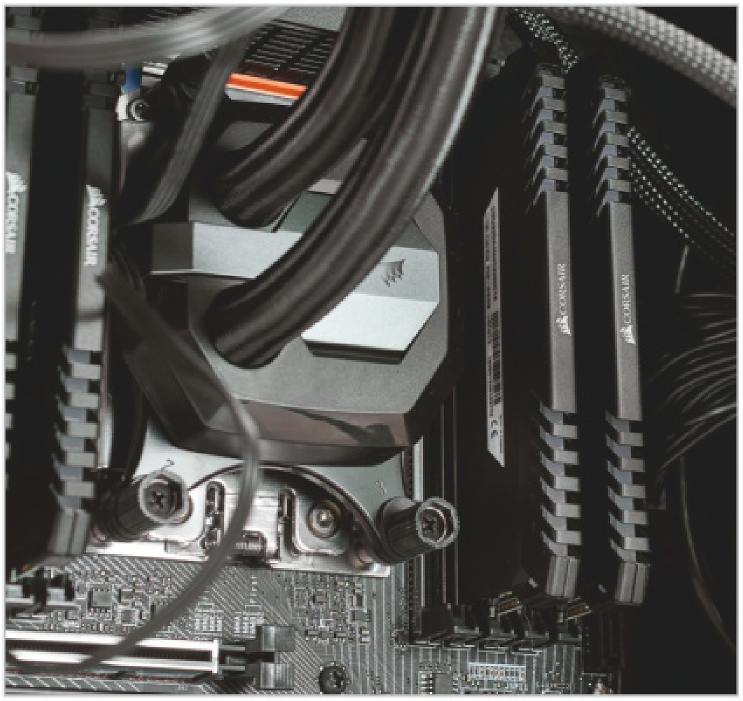
USING AS MUCH from the previous build as possible meant I had a case, graphics card, PSU, some storage, cables, and fans. Pulling the rest out really made me confront the decisions I'd made in 2012, and in subsequent upgrades. Why were there some screws loose in the bottom of the case? We'll never know. It became immediately apparent that the PSU would have to be replaced, because the X399 board requires two CPU power inputs, and the old Corsair unit only had one. A modular supply would help with the tidiness of the build, so one was ordered, with an eye on noise and tidiness, as well as power delivery.

AERO
CORSAIR
RM1000x

2

RULE OF FOUR

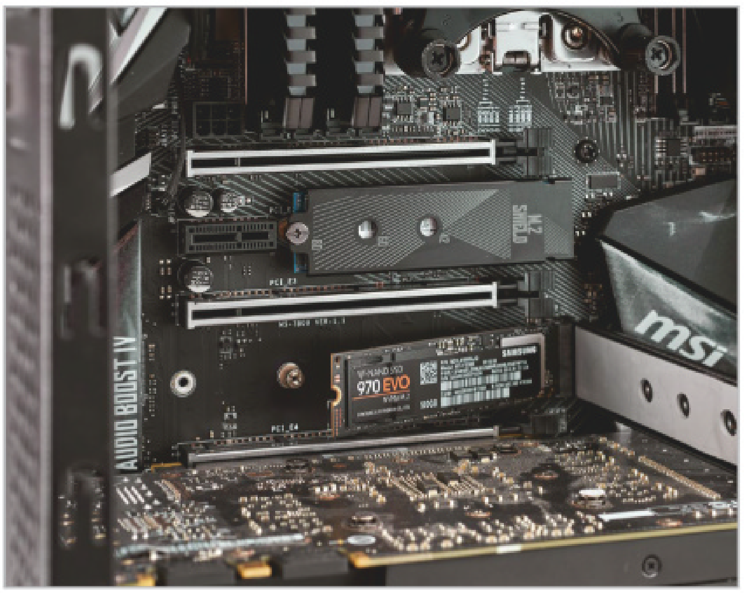
MY FAILURE TO REMEMBER about Threadripper's quad-channel memory architecture saw the initial purchase of Corsair LPX low-profile RAM returned, because I'd bought 2x 16GB instead of 4x 8GB. Its replacement was Corsair Vengeance LED, as prices had changed in the interim, and it clicked easily into place around the socket. I'm old enough to have owned a slot-loading Pentium II, with a Klamath core rocking a whole 266MHz, but for a modern chip, the Threadripper seems excessively large. Once I work out how it slides into the raised arms of the socket, it slips in easily, the bundled Torx driver clamps it down, and suddenly the board is a lot heavier.



3

NVMe VS. SATA

THE USE OF ONE LARGE M.2 drive was meant to streamline the build, but I'd made the silly assumption that they were all NVMe. This isn't true, and the drive I'd bought was plain old SATA III, no faster than my old SSDs. I still wanted the 2TB drive, however, so when a Samsung 970 Evo appeared in an online deal, I snapped it up. This became the boot drive and houses applications, with game libraries on the SATA drive, and the old 2TB hard drive for documents and photos. It looks neat, as the HDD is tucked away near the bottom of the case, and you can't see the M.2s at all under their heat spreaders.



4

TOO TIGHT TO COOL

I SHOULD HAVE NOTICED, but the CPU power connections and one stick of RAM are now right under the CPU cooler's radiator. There's also a weakness in the cooler/case combination—the screws don't quite line up at the back, so the PC ends up with the radiator and its fans hanging out the side of the case while I decide what to do. The Silencio case has almost no space behind the motherboard—it's full of soundproofing foam—so getting the side back on could be a challenge as power supply cables have become thicker over time. With all the power cables attached, I'm looking at the sort of power octopus I wanted to avoid. It boots up happily, though.

5

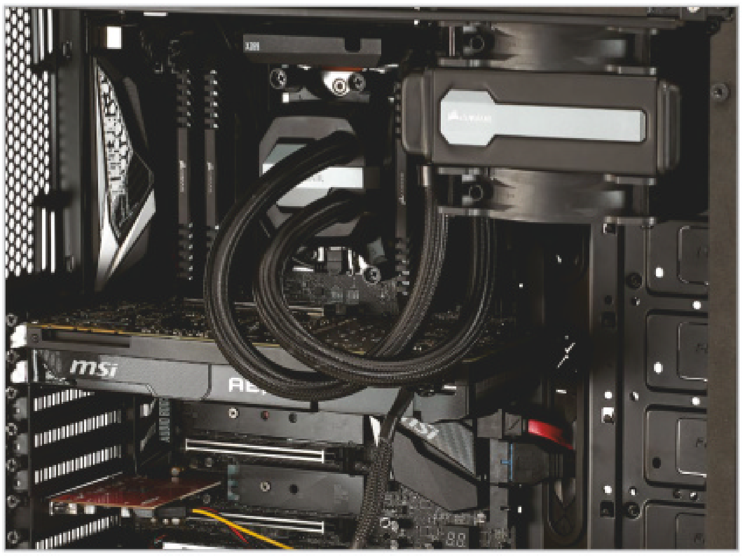
NEW CASE!

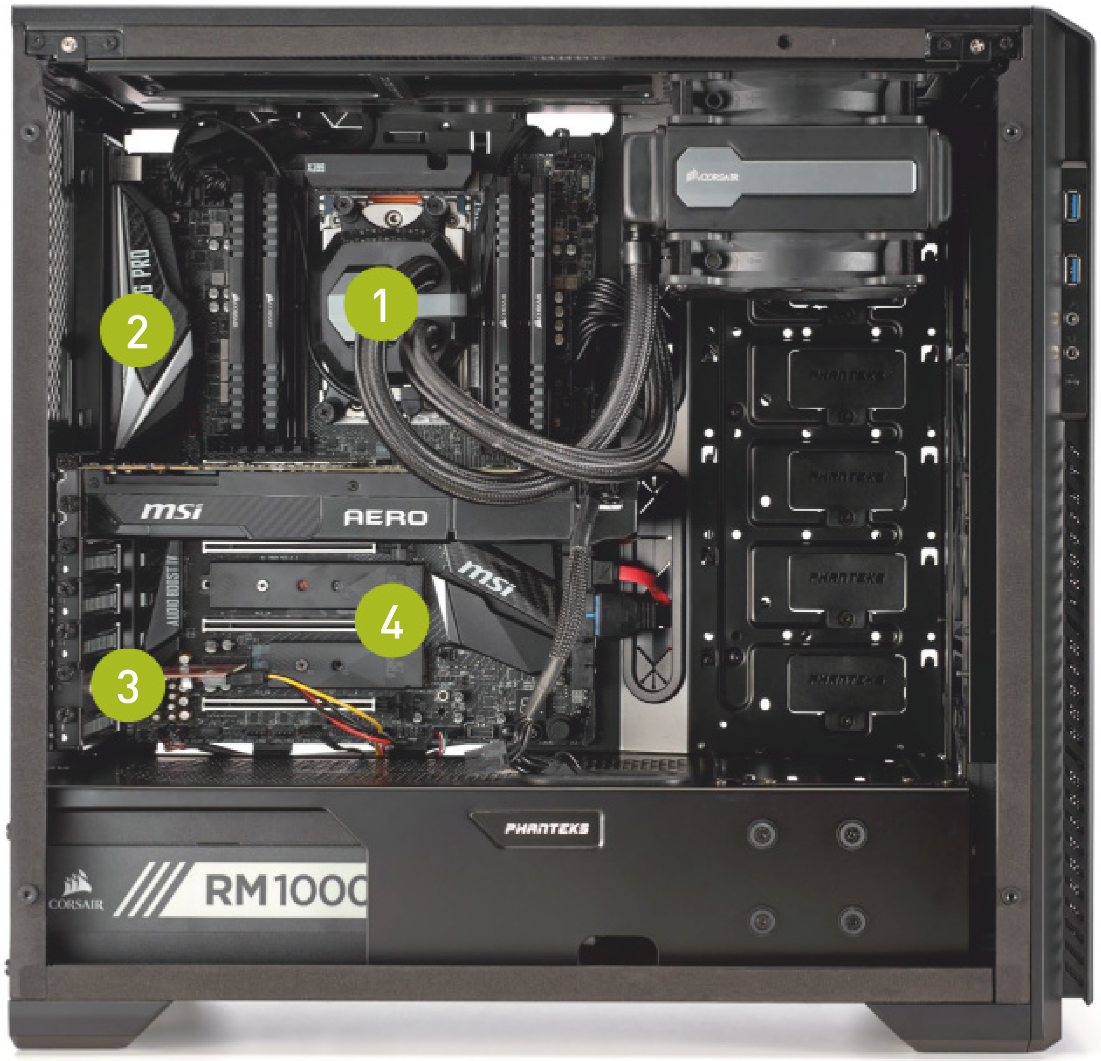
THERE'S ONLY ONE THING to do, and that's to get on the Internet and track down a reasonably priced new case. I choose a Phanteks Enthoo Pro M, as it's similar to my original, but more modern in every way. It also comes with a case window, something I've never had before. Moving everything over gives an opportunity to route the cables properly, and the additional room (along with the supplied cable ties) makes it a much easier job. The only issue I'm left with is that my cooler, being a single radiator with two fans, blocks the lone drive bay, so I can't fit my Icy Box. I'll either change the cooler later or find a way to use the Icy Box externally.

6

FINISHING TOUCHES

WITH EVERYTHING HIDDEN at the back, the view through the window now shows the mobo, GPU, cooler, and one power cable. The HDD is hidden at the bottom, and the M.2 drives are merged with the motherboard. Including Velcro straps and cable ties in the box was a nice touch from Phanteks, up there with the Torx driver bundled with the Threadripper itself. The new case is an inch or so wider than my old one, which means it won't fit in its accustomed position under my desk, leading me to wonder whether I need a new one of those, too. So beware: Upgrading your PC can lead to changing a lot of other things, too!





① The cooler was chosen to fit a different case, so isn't perfectly integrated into this one. Despite this, it does a good job, with the CPU cores rarely topping 65 C.

② The LED-topped RAM is now fully exposed, and can be made to ripple like the *Starship Enterprise's* dilithium chamber.

③ A PCIe card adds four more USB 3 ports to the back of the machine, to make up for the Icy Box not fitting on the front.

④ One of the three M.2 slots remains empty and easily accessible, ready for the inevitable upgrades in the future.

MISTAKES WERE MADE...

IT'S PROBABLY FAIR to say this upgrade didn't go 100 percent according to plan, and in fact, may be a cautionary tale about what not to do. PC components have changed a great deal in six years, even if clock speeds have only inched up. The 2950X's base clock of 3.5GHz is the same as that of the Core i7 it replaces. Elsewhere, though, the increases in memory bandwidth and storage speed, not to mention the processing horsepower of all those cores running at 4.1GHz, thanks to Precision Boost Overdrive, mean it's a much quicker system for some tasks. It's also the first system I've built that has the same amount of RAM as the one it replaces, albeit running at twice the frequency.

This isn't a system built by an expert to show off or demonstrate a point; it's a real-world PC designed to accelerate the gaming and media tasks it's expected to handle, built with an eye on online bargains, and with the desire to recycle components. This last one didn't work so well—only the HDD, graphics card, and a USB 3 card remain from the original—but if this increases the rig's reliability, I'll be happy, as I use it all day, every day. The power supply, in particular, could have blown, thanks to the extra draw.

The main lesson I'm drawing from this is that it pays to plan your build precisely and in detail. The clash between the RAM and cooler probably couldn't have been predicted—who checks the height of their sticks?—and if I'd stuck with the LPX RAM, a lot of trouble could have been avoided. I should have sucked up the price increase, perhaps returning the cheaper LED RAM in favor of something shorter, but I never could resist a bargain. There is such a thing as false economy, though; because of the RAM, I ended up with a new case, and maybe a new desk, and because I failed to discern the difference between SATA and NVMe, I've got two M.2 drives where one would have done.

As the build process neared its end, but before the problems with the case and cooler appeared, I reflected that it was one of the easiest I'd ever attempted. M.2 storage is a vast improvement over sliding drives into cages, mounting them with four screws, and running power and data connections. I'm endlessly thankful for the way RAM sticks can only be put in their slots one way, too, but there needs to be a better way to connect the front panel connections on a case to the motherboard—a bundle of unlabeled, thin wires with plastic blocks on the end isn't ideal, especially when you're dealing with them in the confines of a case. ⏻

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi-Thread	2,178	3,116 (43%)
CrystalDisk QD32 Sequential Read (MB/s)	3,136	3,512 (12%)
CrystalDisk QD32 Sequential Write (MB/s)	2,126	2,304 (8%)
Rise of the Tomb Raider (fps)	68	37 (-46%)
Total War: Warhammer II (fps)	42	27 (-36%)
Tom Clancy's Ghost Recon Wildlands (fps)	38	25 (-34%)
3DMark: Fire Strike (Index)	6,988	4,551 (-35%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our zero-point consists of an Intel Core i9-7900X, 32GB of G.Skill RipJaws V series DDR4 @ 3,000, an MSI GeForce GTX 1080 Ti Gaming X, and a 512GB Samsung 960 Pro PCIe SSD. All tests performed at 4K at the highest graphical profile.

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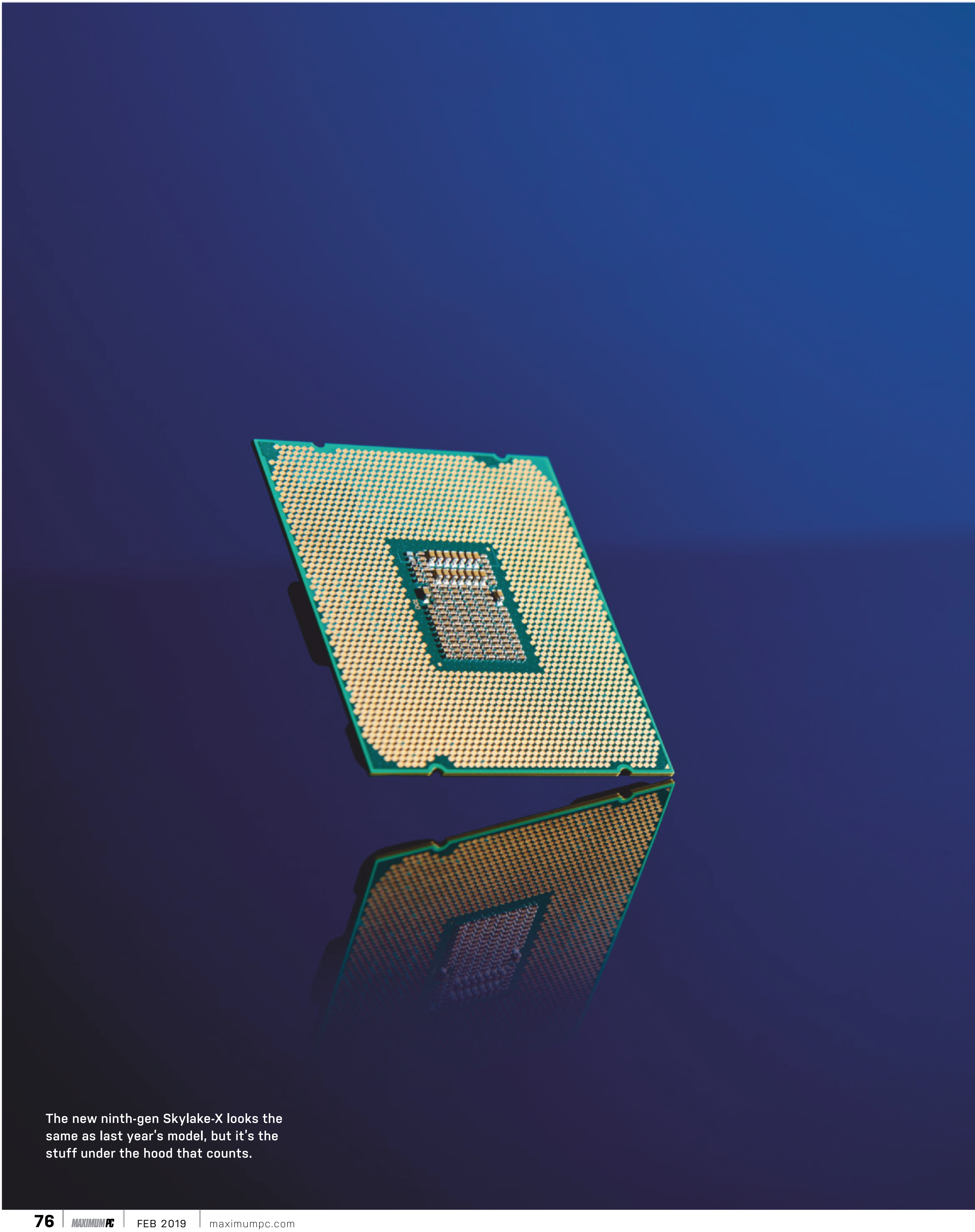


The new ninth-gen Skylake-X looks the same as last year's model, but it's the stuff under the hood that counts.

Intel Core i9-9980XE

Tweaks in manufacturing boost Skylake-X speeds

IF IT FELT LIKE THE HEDT wars got silly over the past year or so, that was only a prelude. AMD took its Zen architecture and doubled down on core and thread counts, the result being the 16-core/32-thread Threadripper 1950X. Intel had no choice but to respond with some one-upmanship of its own and an 18-core/36-thread monstrosity with the Core i9-7980XE. Fast-forward to today, and AMD has continued to push core counts, with up to 32-core/64-thread HEDT products, and 64-core/128-thread server parts. Intel has 28-core Xeon workstation processors, and those will be coming to a different HEDT platform, but with 10nm nowhere in sight, LGA2066 is in a tough spot. That brings us to the updated Skylake-X CPUs and the Core i9-9980XE.

Fundamentally, there's little difference between this Skylake-X part and previous offerings. The architecture is the same, and it's only the surrounding elements that see some changes. Intel has tweaked its 14nm process, now called 14nm++ (14nm+ having been used for Kaby Lake and Coffee Lake). The update increases the transistor gate pitch from 70nm to 84nm, and while that appears to be going in the wrong direction, it allows for higher frequencies. The other major change is that the new ninth-gen Core X-series will switch to a solder thermal interface to help manage temperatures.

Those two changes allow Intel to move the base clock speed from 2.6GHz on the i9-7980XE to 3.0GHz on the i9-9980XE, with the Turbo Boost Max frequency moving from 4.4GHz to 4.5GHz. In practice, at similar power levels, the 9980XE clocks about 200–300MHz higher.

Here's where things get a little weird. Ostensibly, this is a 165W TDP part, like its predecessor. In AVX workloads, the CPU generally adheres to that. But we measured 261W of power draw in Prime95. That's a lot higher than 165W, but nothing compared to the power use in Cinebench, where using an Asus X299-A Prime motherboard, we measured up to 370W. At "stock" if you want to call it that.

Needless to say, our Corsair H115i cooler has difficulty keeping up with such a thermal load, and temperatures can peak at over 95 C, and induce throttling. Behavior in other X299 motherboards can differ, but all the boards we've tested tend to be more than a little aggressive with clock speeds and thermals. That's great for performance, not so great for noise levels or peace of mind. Overclocks of 4.4GHz are possible, with the right cooling solution, but that's a stretch for most users. At stock, all-core clocks are 3.8GHz, but 4.2GHz and above induced throttling with our test rig.

There's also the matter of pricing, which is a weak spot compared to AMD's second-gen Threadripper parts. Per-core performance remains a strong point for Intel's architectures, with the single-threaded Cinebench result reflecting the higher IPC and clock speed. Threadripper performance can also be a bit bipolar, especially with the WX models that have higher memory latencies for two of the CCX modules. That can hurt performance in some applications, including gaming. But professional applications often don't mind so much.

Intel's Core X-series processors still take top honors in applications that leverage AVX instructions, especially AVX512 instructions. Lighter threaded workloads also prefer the higher clock speed and IPC of Intel. But with the right application, Threadripper flexes its muscle and makes even the i9-9980XE look tame—at a far more attractive price.

There's not much incentive to upgrade from last year's model, but if you want lots of high-speed cores and prefer Intel platforms, this is as good as it gets, short of Xeon workstations. At least until 10nm and 7nm parts arrive, which could still be a couple of years away. **–JARRED WALTON**

PROCESSOR BENCHMARKS

	Intel Core i9-9980XE	AMD Threadripper 2970WX	Intel Core i9-7980XE
Cinebench R15 Single (Index)	**199**	172	194
Cinebench R15 Multi (Index)	3,783	**4,407**	3,405
Tech ARP's X264 (fps)	77.07	**81.04**	69.18
Fry Render (m:s)	**1:05**	1:20	1:10
AIDA64 Memory Latency (ns)	68.4	**68**	69
AIDA64 Memory Bandwidth (MB/s)	**90,692**	75,967	90,654
Power Draw Idle/Load (Watts)	92/261	**88**/324	91/**252**
Total War: Warhammer II (fps)	**80**	74	**80**
Ghost Recon Wildlands (fps)	**62**	57	61
Middle Earth: Shadow of War (fps)	**99**	92	98
3DMark Fire Strike (Index)	**19,804**	15,476	19,491
Maximum Overclock @ Voltage (GHz @ V)	**4.4 @ Auto**	4.1 @ 1.43	4.2 @ Auto
Price to Performance (Index)	1.77	**3.44**	1.66

Best scores are in bold. Our test bed consists of an Asus X299-A Prime (Intel), an Asus ROG Zenith Extreme (AMD), 32GB (4x 8GB) G.Skill Trident Z DDR4, an Nvidia GeForce GTX 1080, and a 500GB Samsung 970 Evo. All games were tested at 1080p on the highest graphical profile, with average fps noted.

VERDICT 8

Intel Core i9-9980XE

+ **GIGAHERTZ** Excellent performance; potent AVX abilities; higher clock speeds.

− **GIGAWATTS** Limited overclocking; can draw a lot of power; requires extreme cooling.

$2,142, www.intel.com

SPECIFICATIONS

Base/Turbo Clock	3.0GHz/4.5GHz
Cores/Threads	18/36
Lithography	14nm++
Cache	24.75MB L3
Memory Support	DDR4-2666
Memory Channels	Quad
Max PCIe Lanes	44
TDP	165W

Asus Zephyrus S GX531GM

The battle for ultra-thin gaming rages on

IT'S TIME ONCE AGAIN to present that most tricky proposition: the gaming ultrabook. Here's an ultra-thin, seriously designed piece of gear that looks as capable of passing itself off in a boring meeting as it is at offering up a slice of gaming gateau. But can you really squeeze everything you need for gaming into a chassis that's less than 15mm thick? Let's find out.

This is actually an updated version of the GX501, with an eighth-gen 2.2GHz Core i7-8750H at its heart, and a 144Hz panel. This panel may lack the G-Sync cleverness of the original model, but as it has a lower-powered GeForce GTX 1060 pumping out the pixels, this is less of an issue, as you'll be hard pushed to hit the frame rates needed to make the most of Nvidia's screen-smoothing tech anyway.

The screen itself is a beautiful slice of what's now possible on laptops, and the fact that it's a 144Hz panel means it's silky smooth in operation. This is an IPS-level screen with vibrant color reproduction and great viewing angles, and the decision to stick to Full HD, as opposed a higher resolution, works in its favor, both for usability in Windows and as far as that GPU is capable of driving.

A key part of the gaming proposition is the Armory Crate software, which lets you change the system profiles. The key idea here is that this enables you to throttle back the performance of the CPU and/or GPU in order to keep noise levels down, or alternatively ignore such niceties and go full bore. Normally, profiles have only a slight impact on performance/noise, but here they make a genuine difference.

THE SILENT TREATMENT

For the most part, we're devotees of using the machine in Silent mode, which isn't quite silent, but it is notably quieter than Balanced or the white noise of the Turbo mode. Asus has clearly spent a considerable amount of time honing the cooling here, and the fact that it has squeezed a top-notch CPU and a high-end GPU into such a thin chassis and actually made them usable is impressive. Having said that, don't be fooled into thinking this thing is above the laws of physics—in Turbo mode, it's really freakin' loud.

To give you an indication of the kind of impact this can have, 3DMark produced a score of 10,736 using the Turbo setting, while the same machine managed just 8,097 when running in Silent mode. For our main testing, we left the machine in Balanced mode, which garnered a score of 10,332 in that same 3DMark, which is only slightly off the pace of Turbo setting—although, to be fair, it was vocal in hitting that score.

If you're looking to use this as a gaming machine with the latest titles, you're probably going to want to invest in a good pair of noise-canceling headphones. And be prepared to annoy anyone and everyone around you. Alternatively, playing on Silent mode is a genuine option, and should still see you right in most games, albeit at slightly lower settings and frame rates.

The build quality is generally excellent, with the CNC-milled chassis and lid producing a relatively heavy but solid-feeling device. The way the bottom drops down to aid airflow as you open the screen is particularly pleasing. There is one area that isn't so impressive—the plastic at the bottom of the screen panel is feeble in comparison to the rest of the machine, and flexes to the touch.

There's another version of this machine available from Amazon with the same name, featuring a GeForce GTX 1070 Max-Q in place of the 1060 here, but costing exactly the same. Obviously, we'd recommend bagging that instead, unless you are, for some reason, averse to buying from Amazon—in which case, this model is absolutely fine. **–ALAN DEXTER**

VERDICT

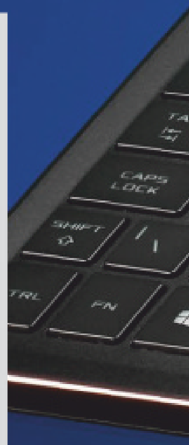
9

Asus Zephyrus S GX531GM

BREEZY Solid design; ultra-thin; vibrant screen; quiet in Silent mode.

HURRICANE Loud in Turbo mode; GPU lacks real grunt.

$1,899, www.asus.com



SPECIFICATIONS

Processor	Intel Core i7-8750H @ 2.2GHz
Graphics	Nvidia GeForce GTX 1060 6GB GDDR5 VRAM
RAM	16GB DDR4-2667
Screen	15.6-inch 1080p 144Hz 100 percent sRGB
Primary Storage	1TB M.2 NVMe PCIe SSD
Keyboard	Backlit chiclet, with 1.2mm key travel
Cooling Solution	ROG Active Aerodynamic System
Battery	Four-cell 50Whr
PSU	180W adapter
Total Weight	4.63lb

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi (Index)	743	1,045 (41%)
CrystalDisk QD32 Sequential Read (MB/s)	563	3,423 (508%)
CrystalDisk QD32 Sequential Write (MB/s)	133	2,786 (1,995%)
3DMark: Fire Strike (Index)	13,202	10,332 (-22%)
Rise of the Tomb Raider (fps)	99	72 (-27%)
Total War: Warhammer II (fps)	62	41 (-34%)
Tom Clancy's Ghost Recon: Wildlands (fps)	48	35 (-27%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our laptop zero-point is the Asus GL502VS-DS71, with an Intel Core i7-7700HQ, an 8GB GTX 1070, and 16GB of DDR4-2400. All game tests are performed at 1080p at the highest graphical profile.

REPUBLIC OF GAMERS

The keyboard and touchpad are quality—once you're used to them.

MSI MEG Z390 Godlike

More glitz than the Vegas Strip

WE'VE SPOKEN A LOT about manufacturers turning away from gaming motifs, jazzy lights, and pointy angles in favor of sleeker designs, a more premium feel, and a better quality of product. It's something we've been requesting for ages. You can tell us that RGB sells, but we think good design sells better.

MSI's MEG Z390 Godlike didn't seem to catch that memo. The layer of over-the-top glam adorning this bulky E-ATX beast was enough to make even our experienced selves take a step back, aghast. From the LED-dotted infinity mirror on the rear I/O cover to the vertically aligned OLED display, showcasing the MSI dragon beating the crap out of some ninjas on startup, to the huge drake motif on the bottom chipset perpetually glowing with rainbow lighting, everything about this screams gauche. There's no subtlety at all. That touch of class we find from the likes of Asus is absent. You could argue, of course, that there's a hole in the market—after all, we don't want every mobo to look like an Asus motherboard—but it's as though MSI saw the latest Formula, and said, "We want that, but x10."

Which leads us to the slight niggle that is performance. Or lack thereof. We get it: Auto-overclocking processors, especially ones as toasty as Intel's Core i7-8700K, isn't a good thing, but it's hard to deny the appeal of that extra performance. Compare this to the Hero, and you lose out by 100 points in Cinebench, nearly 4fps in X264, 10 seconds in Fry Render, and 2ns in memory latency at stock. Power draw is much lower here, with a 26W saving compared to the Hero, but it's not enough for us to start raving about it.

This is meant to be MSI's best and brightest componentry baked into a fine backbone of a mobo, but we're just not seeing it. Take the power delivery: We're talking twin eight-pin EPS, sitting alongside an 18-phase VRM design (which is actually a 16-phase design in reality). Sounds great on paper, but how does it translate to overclocking? Well, our minimum 5.0GHz stability benchmark test achieved a mundane 1.29V versus the Hero's 1.22, and the maximum overclock we managed was 0.1GHz lower than anything we'd achieved prior. Perhaps it's down to Asus supporting a stronger BIOS than MSI, but there really isn't a lot here to warrant much in the way of compliments.

There must be some positives, surely? Well, connectivity is extensively supported. There are three M.2 slots, with dedicated heatsinks, two internal USB 3.1 headers, two USB 3.0 headers, six SATA 6Gb/s, one U.2 connection port (for the 0.001 percent of the market with a device capable of plugging into it), and two USB 2.0 headers. You also get nine PWM fan headers, one AIO pump header, and a waterflow header. There are three

msi
GODLIKE
EXTREME RAPID PRO

RGB headers on the board, too, in case you read out. Plus, there's our all-time favorite JFP1 unmarked header for your front panel connectors (yay!). The one saving grace is the fat audio solution, but there's a lot of fluff here, and not a lot of substance. The rear I/O is seemingly empty in contrast.

Ultimately, MSI's MEG Z390 Godlike mobo tries too hard to be something it's not. The gaming motifs are tired, the LEDs are unnecessary, performance is acceptable at best, and the price is simply absurd. Even the dedicated audio isn't enough to convince us of its value. That's a shame, because MSI could be so much more than it is today—if only the company would take a step back, and try to establish exactly what its market should be. **–ZAK STOREY**

VERDICT

6

MSI MEG Z390 GODLIKE

⊞ **THE ALL-FATHER** OK performance; good audio.

⊟ **IVAR THE BONELESS** Crazy price; under-performer; garish design; ill-implemented OLED display; poor overclocking.

$600, www.msi.com

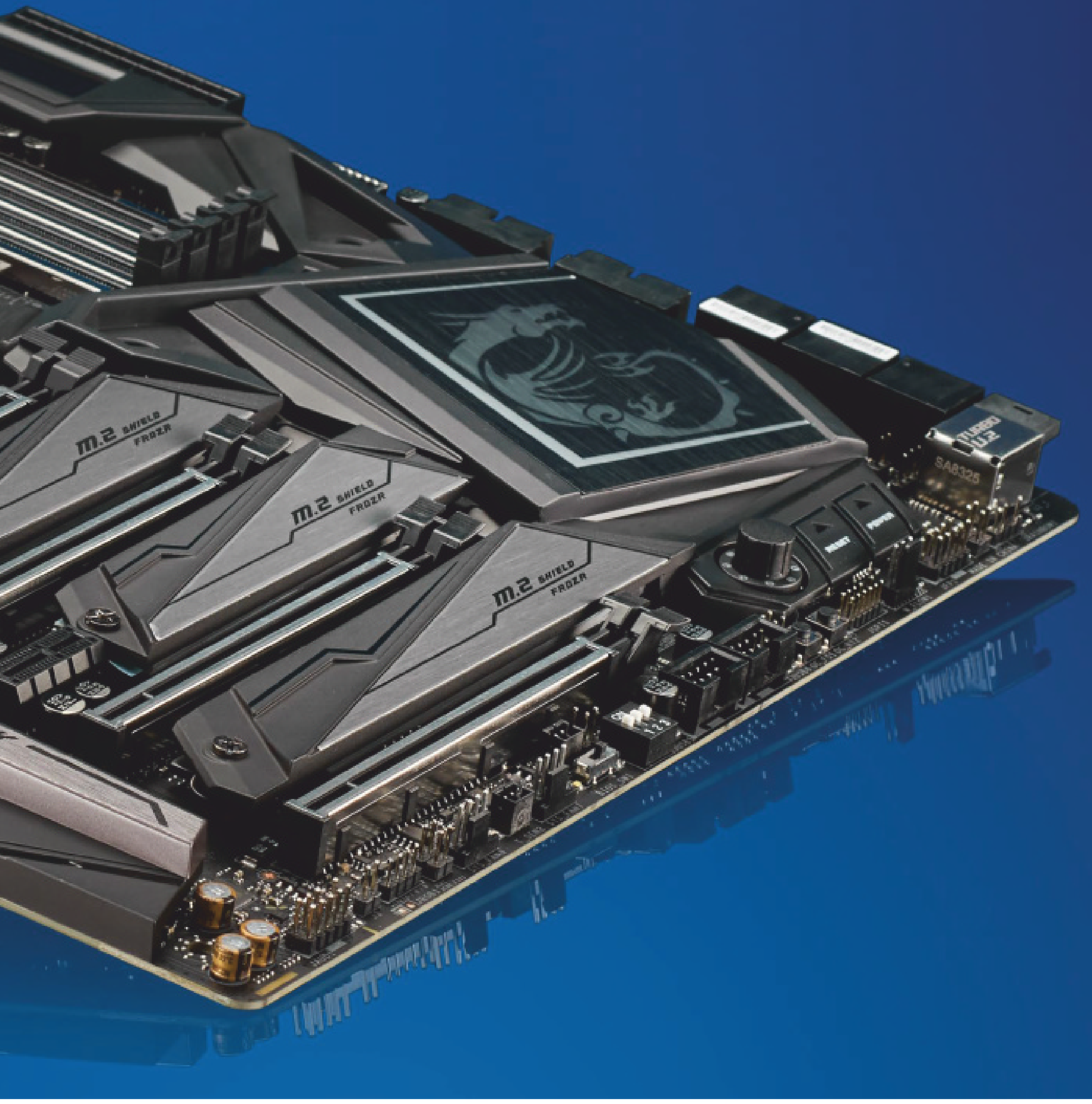
BENCHMARKS

	MSI MEG Z390 Godlike	Asus Maximus X Hero
Tech ARP's X264 (fps)	30	**33.91**
Cinebench R15 Multi (Index)	1,424	**1,522**
Fry Render (m:s)	2:23	**2:13**
AIDA64 Memory Latency (ns)	50.4	**48.1**
CrystalDisk QD32 Sequential Read (MB/s)	548	**551**
CrystalDisk QD32 Sequential Write (MB/s)	**523**	513
Power Draw Idle/Load (Watts)	**50/310**	65/336
Total War: Warhammer II (fps)	**56**	**56**
Lowest Voltage @ 5.0GHz (Volts)	1.29	**1.22**
Maximum OC Achieved (GHz)	5.0 @ 1.29V	**5.1 @ 1.32V**

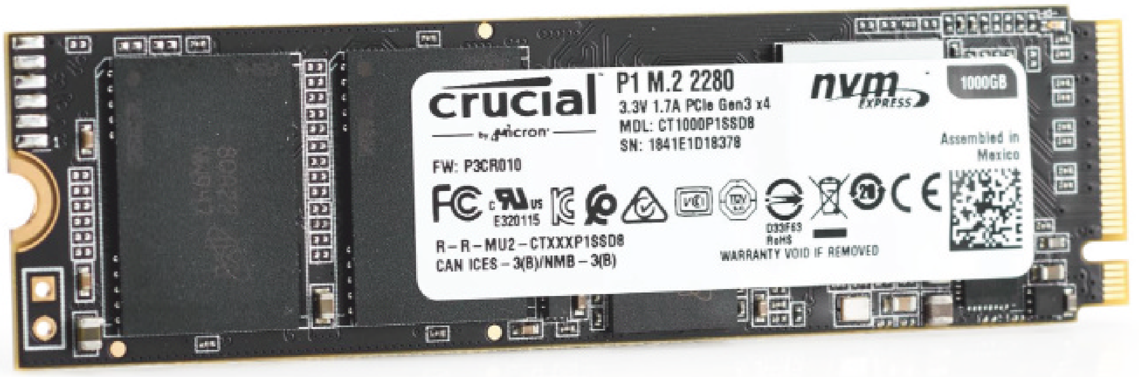
Best scores are in bold. Our test bed consists of an Intel Core i7-8700K, 16GB of Corsair Dominator Platinum DDR4 @ 3,000MT/s, an Nvidia GeForce GTX 1080, and a 250GB Samsung 860 Evo SSD. *Total War: Warhammer II* was tested at 1440p on the ultra preset.

SPECIFICATIONS

Chipset/Socket	Z390/LGA 1151
Form Factor	E-ATX
Memory Support	64GB DDR4 @ 4,600MT/s
M.2/U.2 Support	3x M.2 PCIe x4, 1x U.2
SATA Support	6x SATA 6Gb/s
Max PCIe Support	4x PCIe x16
Rear I/O	5x USB 3.1 Type A, 1x USB 3.1 Type C, 2x RJ45 Gigabit Ethernet, 5.1 audio out, optical audio out, PS/2 combi port, wireless A/C, headphone out, Clear CMOS & BIOS Flashback button



It's a nice attempt, but MSI has missed the mark with this one.



Crucial P1 1TB

Crucial's new SSD is a quad-level conundrum

INCREASED STORAGE CAPACITY comes at a price. That's not exactly a revolutionary idea, but it is more complicated than it sounds. That's because the costs involved aren't just dollars and cents; they can also be measured in performance and endurance terms.

Those latter concerns are front and center with Crucial's P1 drive, its latest M.2 NVMe drive, reviewed here in 1TB configuration. It's one of the first on the market to use Intel and Micron's new QLC or quad-level cell NAND flash memory. That's one bit up on the previous industry best that is TLC or triple-level cell memory. In simple terms, the appeal is obvious. The extra bit makes for 33 percent more storage capacity per cell. However, the downsides can be brutal.

In layman's terms, upping the per-cell capacity of NAND flash makes it more fragile. A single-level cell, for instance, can handle something like 100,000 program-erase cycles before conking out. That endurance progressively degrades as you add cell capacity. By the time you get to QLC memory, you're looking at just 1,000 cycles before a cell is toast. In practice, wear-leveling algorithms ensure that won't actually be a major concern for most home users, but it does illustrate the cost of increasing capacity via cell density.

As for performance, we detailed in last issue's feature on the state of SSD tech that reading and writing to multi-level NAND cells is increasingly laborious as per-cell density increases. It requires distinguishing between and applying 16 possible voltage levels in each cell. That limitation is more apparent in practice than the impact on endurance.

PERFORMANCE ART

A quick thumb-in-the-air evaluation of the new P1 reveals that sequential data transfer performance eventually drops off to about 60MB/s if you throw enough data at the drive. What's happening is obvious: The P1 relies on an allocation of its memory operating in SLC or single-level cell mode to deliver its claimed peak performance of 2,000MB/s reads and 1,700MB/s writes. Once that is exhausted, the true underlying performance of those QLC cells is exposed. And it ain't pretty.

You won't always see that limitation in synthetic tests. Although the P1 doesn't get on that well with CrystalDiskMark's sequential throughput test, it still cranks out pretty quick numbers of 1.15GB/s reads and 1.7GB/s writes, for instance. That said, the P1's performance in Anvil's QD1 random access benchmarks is disappointing; 32MB/s for reads and 126MB/s for writes are not disastrous, but remain a little off the pace for a modern M.2 NVMe drive.

Our more real-world 30GB internal file copy test is also a mixed bag. The P1 completes it in 60 seconds, which means most of the data transfer is managed before the SLC cache runs out. But a high-quality drive that doesn't rely on SLC caching, such as Intel's Optane 905p, can burn through the data transfer in about half that time.

In the end, the P1 is posed with two critical questions. First, how often are you likely to bump into the P1's built-in limitations? Unlike the ADATA SU630 opposite, which uses the same QLC NAND flash memory, we'd say not that often. However, the problem the P1 shares with the ADATA drive is its answer to the second question. Does it provide an advantage in terms of cost per GB?

At this price point, you have a number of TLC options, and this QLC drive doesn't offer a clear value advantage on capacity alone. That may be because, reportedly, Intel and Micron are having problems manufacturing QLC NAND at yields healthy enough to make drives much cheaper than the TLC alternatives. Whatever the truth about that, the fact is that QLC technology isn't cheap enough now to offset the impact on performance and endurance. –JEREMY LAIRD

VERDICT 7

Crucial P1 1TB

➕ **FOUR IS MORE** QLC promises more capacity for less cash.

➖ **PLEASE, NO MORE** In practice, QLC is yet to fully deliver; patchy performance.

$170, www.crucial.com

BENCHMARKS

	Crucial P1 1TB	Samsung 970 Pro 512GB
30GB Internal Copy (Seconds)	60	**29**
CrystalDisk 6 Sequential Read/Write (MB/s)	1,149/1,708	**2,788/2,331**
Anvil 4K QD 1 Read/Write (MB/s)	32/126	**48/141**
Anvil 4K QD 2 Read/Write (MB/s)	60/242	**91/281**
Anvil 4K QD 4 Read/Write (MB/s)	100/443	**152/524**

Best scores are in bold. Our test bench consists of an Intel Core i7-8700K, an Asus Maximus X Hero, an Nvidia GeForce GTX 1080, 16GB of Corsair Dominator Platinum DDR4, and a Samsung 850 Evo 250GB OS SSD.

SPECIFICATIONS

Capacity	1TB
Interface	M.2
Control Protocol	NVMe
Controller	Silicon Motion SM2263
NAND Type	3D QLC
Sequential Read and Write	2GB/s and 1.7GB/s
Read/Write IOPS	170K/240K
Warranty	Five years

ADATA SU630 480GB

Turns out QLC isn't quite more storage for free...

BE CAREFUL WHAT YOU ASK FOR. You might just get it. Like, say, affordable solid-state technology for mass storage. That's the end game we're all after, isn't it? Kiss goodbye to slow, failure-prone magnetic hard drives. It's also why the new ADATA SU630 exists. At least, that ought to be why it exists. To deliver more solid-state storage for less money than before, while perhaps compromising a little on performance. Hold those thoughts.

To cut to the chase, the ADATA SU630's not-quite-USP is QLC, or quad-level memory cells; in this case, Intel's QLC NAND, and thus the same memory chips as those used by the Crucial P1 (reviewed opposite). You should read that review for a little more insight into the technological nuances of QLC memory. Suffice to say here that QLC is the next step on, obviously enough, from TLC, or triple-level cells, and the immediate benefit is more memory capacity per cell. The upshot should be cheaper SSDs, and with that a step closer to the aforementioned solid-state nirvana.

In this case, we're talking old-school SATA connectivity and a 2.5-inch form factor, which is just dandy, given the entry-level mass storage remit. The headline figures ADATA claims look fine, too: 520MB/s for sequential reads and 450MB/s for writes. Admittedly, the 45,000 random read IOPS and 65,000 random writes aren't the stuff of technological legend, but it's hardly a horror show, either. More of a concern is the SU630's claimed endurance. For this 480GB model, ADATA is pegging the drive at 100TB of total write endurance. That's one third of the endurance ADATA says its TLC drives are capable of. Ouch. It's the most obvious indication, on the spec sheet at least, that the increased capacity of QLC NAND comes at a cost.

While we're talking speeds and feeds, we'll note that ADATA does not specify the SU630's controller, but it probably rocks a Maxio Technology MAS0902A-B2C. That's on the basis that it's one of only two controllers that claim support for QLC NAND, and the other is from Phison, a company ADATA is not previously known to have partnered.

ADATA also doesn't divulge how much of the SU630's QLC NAND is provisioned for operating in higher performance pseudo-SLC mode, for the purposes of providing a cache buffer before you hit the true performance of the QLC cells. However, it's in the order of a few gigabytes. During our usual pre-test flight checks, which typically involve filling the drive to full at least once before wheels-up, we noted that the sequential performance of the SU630 cliff-edges very rapidly. And we do mean that fairly literally. After a few gigabytes of sequential work in line with the drive's 500MB/s-plus claimed performance, throughput craters to around 38MB/s and stays there. Yuck.

That issue, obviously, doesn't show up in the synthetic tests. The SU630 looks plausible enough in CrystalDiskMark and Anvil Storage. Indeed, that plausibility extends to random performance. OK, its performance for 4K random reads and writes at the various queue depths is not in flaming undergarments territory. But it's OK. Definitively not OK is the SU630's showing in our 30GB internal file copy test. Here, again, the true performance of that QLC NAND is exposed. It takes the SU630 nine minutes, 31 seconds to complete the test. Which is awful.

That doesn't automatically have to be a deal-breaker, of course. If you're not regularly shunting large files around, it could even be irrelevant. The caveat to that, we'd argue, is that if you're going to tolerate both poor underlying performance and limited endurance, you'll want something in return. That something would be a ridiculously low price. And while cheap, the SU630 isn't nearly cheap enough. **–JEREMY LAIRD**

VERDICT

6

ADATA SU630 480GB

+ THEORY Looks good on paper; uses cutting-edge QLC NAND memory.

– REALITY Feels pretty crappy in practice; faster drives available for similar cash.

$58, www.adata.com

BENCHMARKS

	ADATA SU630 480GB	Samsung 860 Evo 500GB	Crucial BX500 120GB
30GB Internal Copy (Seconds)	571	**89**	224
CrystalDisk 6 Sequential Read/Write (MB/s)	**563**/522	**563/533**	561/238
Anvil 4K QD 1 Read/Write (MB/s)	39/111	**50/119**	31/112
Anvil 4K QD 2 Read/Write (MB/s)	69/212	**98/225**	53/197
Anvil 4K QD 4 Read/Write (MB/s)	132/295	**182/314**	87/207

Best scores are in bold. Our test bench consists of an Intel Core i7-8700K, an Asus Maximus X Hero, an Nvidia GeForce GTX 1080, 16GB of Corsair Dominator Platinum DDR4, and a Samsung 850 Evo 250GB OS SSD.

SPECIFICATIONS

Capacity	480GB
Interface	SATA 6Gb/s
Control Protocol	AHCI
Controller	Maxio Technology MAS0902A-B2C
NAND Type	Intel 3D QLC NAND
Sequential Read/Write	520/450MB/s
Read/Write IOPS	45/65K
Warranty	Two years

LG 27UK600

LG enters the HDR fray

EVENTUALLY THE BRAVE new world of HDR will settle down into something we can all understand. For now, it's a battle of standards that must surely leave the average screen buyer utterly baffled.

Enter LG's latest HDR-capable panel, the 27UK600. On the one hand, it offers HDR 10 support and, with that, 99 percent of the sRGB color space. On the other, it's good for peak brightness of 450 nits and doesn't support local dimming. Granted, there is no definitive definition of where standard dynamic range displays end and HDR begins. But for an LCD monitor to be truly classified as HDR, we reckon it needs to be brighter than that and have a backlight with local dimming capability.

What else do you need to know about the new 27UK600? As the name implies, it's a 27-inch model. It's also a 4K screen, with an IPS panel type, a 3840x2160 native resolution, and support for AMD's FreeSync adaptive refresh technology with a refresh rate of up to 75Hz, the latter two features only available with AMD graphics cards. Hooked up to Nvidia cards, it's a conventional 60Hz panel.

What's absent is USB-C connectivity. There's DisplayPort and HDMI, but the flexibility of USB type-C, including the ability to charge a laptop and drive the display with a single cable, is missing.

So, what does LG's latest look like when you fire it up? Pretty darn nice. It's immediately obvious you're looking at something a little beyond the SDR norm. The colors pop just that little bit more, but without the cheesy oversaturation you get with some VA screens. The accuracy of the IPS panel is obvious. The moderately slim bezel also makes for a fairly contemporary feel, although it's not nearly tight enough to make pairing multiple examples of the 27UK600 resemble a single-display solution.

Subjective contrast performance is strong, too, and if anything exceeds the modest expectations that come with LG's claims of 1,000:1 contrast capability from the IPS panel. 4K squeezed into a 27-inch panel also makes for a tight pixel pitch and nice font rendering, even if it's not going to rival your phone for crisp fonts.

Where things get more complicated is with the screen's HDR functionality. Enable HDR in Windows and play some HDR content, and the results are a mixed bag. The HDR content itself looks pretty good. Not as stellar as a display with local dimming, like the Acer X27, but a step up in terms of vividness over an otherwise comparable SDR panel. Less satisfactory is SDR content in HDR mode, including the Windows desktop and Windows apps.

Windows 10 now includes a so-called brightness slider to tweak the appearance of SDR content in HDR mode. With the Acer X27, the results are excellent. Not so with the LG 27UK600. Even at maximum brightness, SDR content is muddy and off-color. The net result is that you'll have to jump back and forth between SDR and HDR modes. For the record, the 27UK600's HDR Effect mode isn't a winner, either. You'd never use it for general computing; it does strange things to the color balance. And while it does add some punch to video content, the results aren't terribly natural or convincing.

All of which means that as an HDR panel, the 27UK600 comes up short. However, if you view it as a very capable SDR panel with a little HDR ability, it's far more compelling. If it had USB-C connectivity, it would be even better. But as it is, it's still worthy of our qualified recommendation. **–JEREMY LAIRD**

VERDICT **8**

LG 27UK600

+ DYNAMIC High-quality 4K IPS panel; reasonable performance with HDR content.

− DREARY SDR content looks poor in HDR mode; lacks local dimming and USB-C.

$480, www.lg.com

SPECIFICATIONS

Panel Size	27-inch
Native Resolution	3840x2160
Pixel Density	163.18
Panel Type	IPS
Maximum Refresh	75Hz
Response	5ms G2G
Contrast	1,000:1
Display Inputs	DisplayPort, 2x HDMI
Connectivity	N/A
VESA Mount	100x100mm
Warranty	One year

For the 27UK600, LG has opted for HDR 10 support.

Roccat Kone AIMO

Evolutionary advancement

CAN WE ALL JUST take a moment to appreciate how frigging difficult it is to find a good mouse? Seriously, the list of trending pixel pointers is seemingly endless. Couple that with the variety of hand shapes and grasping preferences out there, and a severe lack of places to try these critters outside of the realms of cyber-space, and what you're left with is a headache. A headache, and an over-reliance on reviewers and YouTubers using poorly sized banana analogies to compare size. As if that's some hilarious joke we'll all collectively laugh at. It's a tough one, that's for sure.

So, what should you be thinking about when it comes to the perfect mouse? Well, there's its weight and shape—are you a lefty or a righty? Do you need it to be wired? Are you a gaming professional? An office user only? Or would you prefer an all-arounder? What about sensors? Laser? Optical? Do you want one with low jitter? How high do you like your DPI? Adjustable lift-off distance?

We could go on for days and bamboozle you (and arguably us, too) with specs and design choices, but what the average user should be looking for ultimately is a good all-arounder. A mouse that looks at the market, goes "Huh, this is all rather complicated," then takes the very best of everything, and uses it in such a manner that you barely even notice it's there. Oh, and slaps on a $80 price tag, too. Not so expensive that you spit out the morning cup of joe all over our mag, but also not so cheap that you lose out on all those subtle features.

The Kone has long been Roccat's mainstay product. It's a mouse brand that pulled the company from obscurity and gave the German manufacturer a sizable chunk of market share—and with good reason. It was solid, it looked good, and it did everything you wanted it to, without fuss, without worry, and without milking your bank account. That, however, was over 12 years ago, and today we're witness to the Kone AIMO.

There have been some considerable advancements since then. The design is more ergonomic. The material, although not rubberized, is now a soft, satin plastic. The buttons are intelligently placed, within easy reach of your thumb. And the lighting is encapsulated in beautifully frosted plastic, so it can better diffuse those RGB LEDs.

OWL FAITHFUL

The showpiece, however, is the PixArt PMW3361 optical sensor, located at the heart of the device. Arguably the most important piece of this puzzle, Roccat is calling this its Owl-Eye sensor. It's essentially a slightly tweaked variant of the PMW3360, custom built for Roccat, and is currently regarded as one of the best sensors in the business. Held up high by the likes of the top 1 percent of esports enthusiasts and athletes who earn way more money than makes sense, the PMW3360 is by far the best sensor out there.

Why, you ask? Well, it all comes down to how the PMW3360/61 handles hardware acceleration—basically, there isn't any. Below the 2,500 dpi mark, there's little to no smoothing. What you get is what you give, which means that precision is assured—whether you miss or hit the shot, it's on you, not the mouse, not lag, you, and there's something quite satisfying about that.

The saying goes, "A jack of all trades is a master of none," but that isn't the entire quote; it ends with, "But oftentimes better than a master of one." In the end, it's far better to be versatile and adept across multiple spectrums than a specialist in just one area, and there's no better example of that ethos made manifest than the Kone AIMO. Yeah, it isn't absolutely perfect. It's not super-light, it doesn't have all the buttons, it's not got a rubberized finish, there isn't a plethora of macros, or a plastic cable, and it doesn't support every single style of grip perfectly. But what it does do is combine the best of what it can, in a way that'll never let you down, and for that we absolutely commend it. **–ZAK STOREY**

VERDICT
9

Roccat Kone AIMO

⊞ **RAVEN** Versatile; incredible sensor; good use of materials; solid price.

⊟ **PIGEON** Won't suit all grips; big.

$80, www.en.roccat.org

SPECIFICATIONS

Sensor	Optical
Sensitivity	12,000 dpi
Sensor Model	PixArt Technologies PMW3361
Polling Rate	1,000Hz
Programmable Buttons	3
LEDs	Three zones, 16.8 million colors
Cable Length	6 feet

Razer Nari Ultimate

When music moves you—literally

WHAT WE PERCEIVE as "normal" is something society instills in us from a very early age. We can comprehend a table as being a table because that's what we're told it is. It is, essentially, just four sticks of wood at the corners, with a flat piece on top. It could be a chair, bed, toilet, statue, art, but we've been taught from childhood to recognize it as a table. Using it as anything else would be odd. The problem with that notion is that it stifles creativity. It doesn't allow for thinking outside the box.

All design seems to stem from that principle. You take something we know, and change it to make it better, but only so far as it doesn't exceed the original parameters of its classification. It might be a round table, with better hinges, and a nice finish, but it's still a table.

This is why innovation is such a slow process. Due to the way a capitalist market works, companies tend to hedge their bets. It's far better to lie on the side of caution with predictable profit growth than venture out into the unknown with a product that might not sell because it tries something different. Think about it: All the big innovations over the years have typically come from small start-ups with massive ideas.

It's a particular problem in the world of peripheral design. Because no one is willing to challenge what a peripheral can be, all changes are typically iterative. Slight alterations in style, improvements in technology, lighter, thinner—you get the picture. Small companies pioneer a new design, it catches on, becomes successful, then the big companies follow suit two or three years later. RGB LEDs, optical sensors, mechanical switches, USB C, wireless charging....

Why this massive preamble? Because of what Razer has done here—what we're trying to say is: "You need to give them a chance before you judge them." The Razer Nari Ultimates are a pair of headphones with haptic feedback built into each earcup. Powered by Lofelt, the vibration motors dynamically adjust depending on the amount of bass being pumped through the drivers. It works seamlessly across multiple devices, via USB, analog, and wirelessly, and without any proprietary software.

LOBETROTTERS

It's certainly different. It's quite strange to have your ears vibrated. Depending on the size of your lobes, you may find it vibrates around them, too. In game, it's a welcome touch—the sound of your spells ricocheting off mobs, or bullets firing from your rifle as you lay into some zombies, makes for a surreal experience.

Music and entertainment are in a similar boat—although, more dependent on the song in question, sometimes it works, sometimes it doesn't, sometimes it's just annoying. Overall, sound quality is solid and the soundstage is rich, with plenty of mids and just enough highs to keep things well rounded, and the bottom end isn't too overly saturated either.

We love what Razer is doing here; trying to innovate in this market is difficult and definitely risky. The vibration drivers are interesting and fun at first—however, we're concerned that those vibrations may become a nuisance over time, rather than something you enjoy, and with no way of turning them off (Razer Synapse option, please), it does make us wonder whether the $200 investment is worth it in the long run.

The Nari Ultimates are well rounded, clean, comfortable, and impressive, so far as innovation goes. However, the biggest limiting factor is those vibration drivers. We understand the desire to just have them work, without any proprietary software control, but the inclusion of even just an on-device button to enable and disable them would've been welcome. Razer, we like what you're doing here—it's an intriguing concept—but we need iteration two before we can really recommend it. **–ZAK STOREY**

VERDICT

7

Razer Nari Ultimate

⊞ **VIBRATO** Clean soundstage; connectivity; innovative; comfy.

⊟ **JACKHAMMER** No off switch for haptic; risky investment because of it.

$200, www.razer.com

SPECIFICATIONS

Driver Type	50mm dynamic neodymium
Impedance	32 ohms
Frequency Response	20Hz–20kHz
Microphone Type	Unidirectional
Connectivity	Four-pole, USB, wireless 2.4GHz
Range	40 feet
Battery Life	Eight hours
Weight	0.9lb

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Phanteks Enthoo Pro M Tempered Glass

A lesson in efficient chassis design

A QUICK HEADS-UP: You're going to read the beginning of this review and say, "What on earth are you on about?" But keep on reading and hear us out before you turn the page, because hopefully it'll all make sense. Probably.

If there's one thing that separates a good manufacturer from a bad one, it's intelligent use of design. Take VW, for example, or more specifically, the VW Group. Across a broad range of its vehicles—from its SUVs to its hot hatches to its sports cars—it uses a single chassis design: the MQB platform. Whether it's a $44,000 Audi TT, a $21,000 VW Beetle, or a $31,000 4x4 Tiguan SUV, at the heart of them all lies the MQB chassis. There's good reason for this: The design is modular, it's easy to adapt, and with an arsenal of easily attachable components and panels, whatever you need it to be, it can be. It's versatile, it's adaptable, and, most importantly, it saves a ton of money for Volkswagen, which means bigger savings can be passed on to the buyer. In theory, at least.

The reason we're bringing this up so flippantly is because Phanteks seems to be following a very similar methodology with its tower case lineup, albeit without the grandiose nature and a mass arsenal of brands to power it. The Evolv ATX, Evolv ATX TG, Enthoo Pro M, Enthoo Pro M TG, Eclipse P400, and Eclipse P400S all, at their core, feature the same internal chassis, the same internal layout, and the same feature set, which is no bad thing.

With it, you get support for up to E-ATX motherboards, rear-mounting SSD trays, cable grommets, a huge CPU tray cutout, integrated Velcro ties, liquid-cooling pump-mounting brackets, a sliding top radiator bracket, noise dampening as standard, a front SSD mount, a PCIe cable pass-through cutout, and some seriously solid ventilation at both the top and bottom of your PSU cover.

On top of all that craziness, Phanteks has also managed to bake in a 5.25-inch drive cage and extensive cooling support, for up to three 120mm or two 140mm fans in the front, ditto in the roof, and a single 140mm fan in the rear. It's an absolute beast, to say the least, and the fact that the company is pushing this internal chassis, or a very similar design, into a wide array of its products is a blessing.

Why? Well, simply put, regardless of whether you invest $190 into a premium case or $70 into a budget variant, you're essentially still getting the same compatibility, and the same quality of life improvements. It makes a world of difference. Of course, there's always going to be some cost cutting when it comes to these things, but for the money, it's hard to find a better specced case.

That doesn't mean the Enthoo Pro M is flawless. It's a nice budget chassis, for sure, but it does lack some of the pizzazz you'll find in the other offerings, even the cheaper ones. Its saving grace is that extensive compatibility we mentioned earlier. The big advantage, however, is the 5.25-inch bay—with so few cases on the market nowadays supporting the old standard, if you're clinging on to your old CD drive, the Pro M may be your last bastion when it comes to buying a modern chassis. –ZAK STOREY

VERDICT 9

Phanteks Enthoo Pro M Tempered Glass

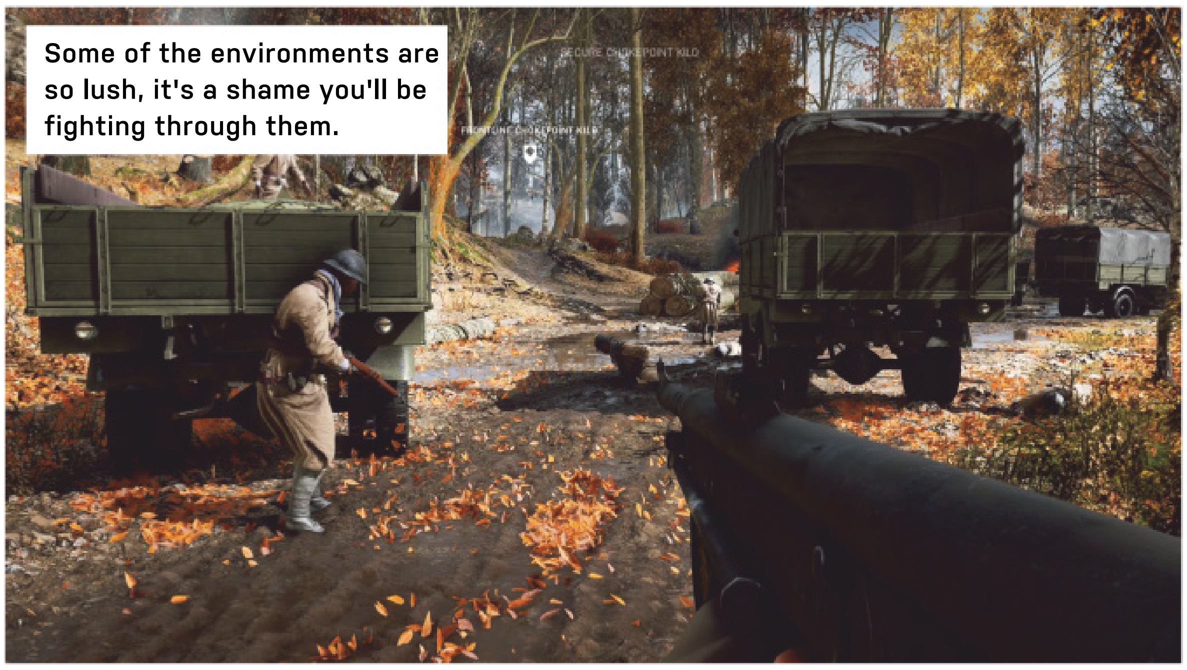
+ ENTHOOSIASM Incredible internal layout; strong cooling support; competitive price; tempered glass.

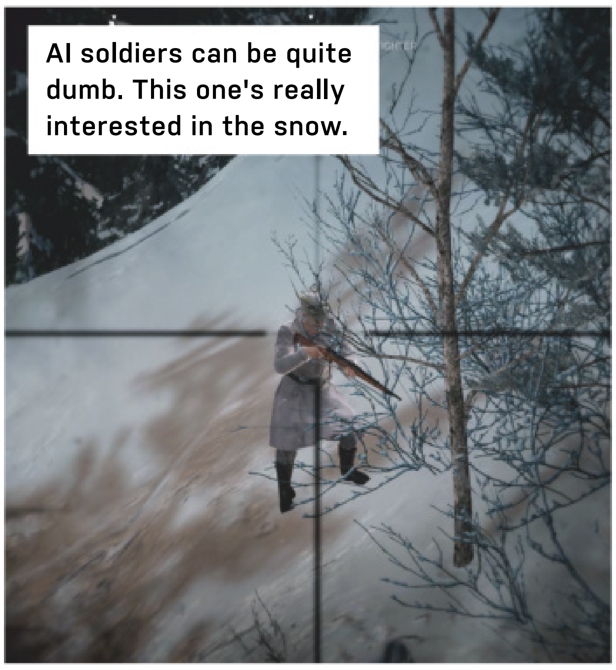
− ENTHY Not very classy; finish could use some work.

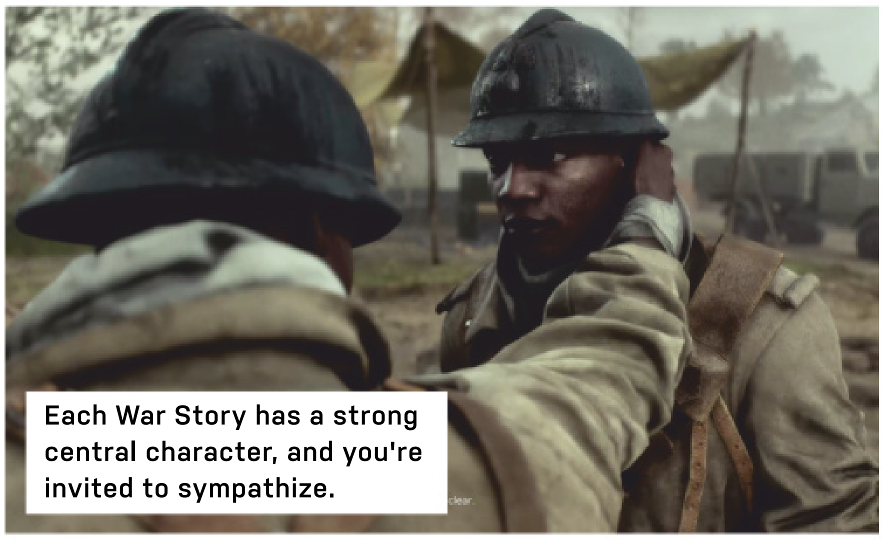
$100, www.phanteks.com

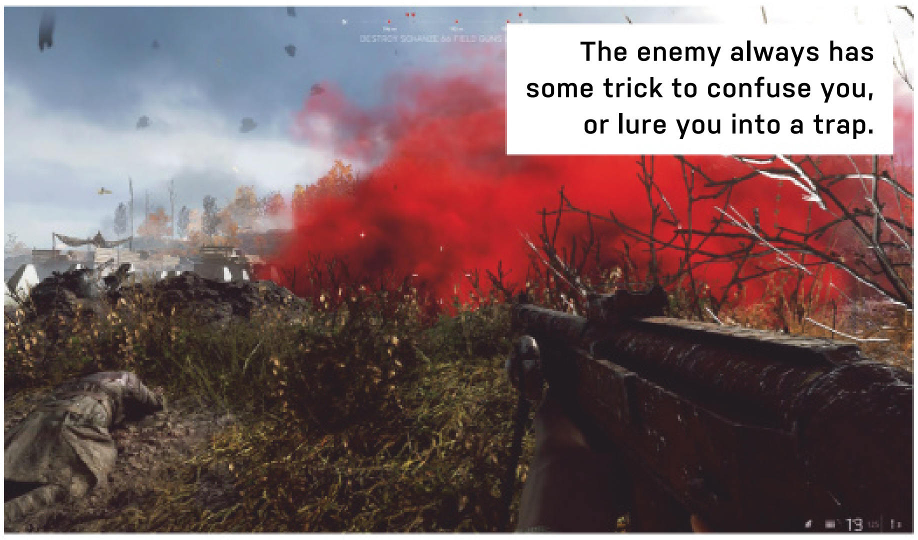
SPECIFICATIONS

Form Factor	Mid tower
Motherboard Support	E-ATX, ATX, mATX, Mini-ITX
Colors Available	Satin black
Window Available	Plexi or tempered glass
3.5-Inch Support	8x (3x included)
2.5-Inch Support	3x (1x included)
Radiator Support	360mm front, 360mm roof, 120mm rear
Fan Support	3x 120mm front, 3x 120mm roof, 1x 120mm rear
Dimensions	9.25 x 18.9 x 19.7 inches
Graphics Card Clearance	16.54 inches
CPU Tower Clearance	7.6 inches
Weight	15.4lb


Some of the environments are so lush, it's a shame you'll be fighting through them.


AI soldiers can be quite dumb. This one's really interested in the snow.


Each War Story has a strong central character, and you're invited to sympathize.


The enemy always has some trick to confuse you, or lure you into a trap.

Battlefield V

It's World War II again, now looking better than ever

WAR, ACCORDING TO the *Fallout* games, never changes. It doesn't in *Battlefield,* either, despite the rising tide of battles royale that have forced even *COD* to bend before their power. The latest installment in EA's series couldn't be more traditional at launch, from its World War II setting to its single-player campaign.

There's a more modern tradition in evidence, too: The game, at the time of writing, isn't all there. There's no co-op mode yet, and one of the single-player missions—collectively known as War Stories—is also missing in action, and bound to cause controversy when it appears, putting you in the turret of a German tank. You'll have to wait for the inevitable battle royale mode, too.

The War Stories themselves are nicely written, and put up a decent challenge. The first, which sees a British bank robber sprung from jail, so he can use his explosives skills to inconvenience the Nazis, is an entertaining romp, but teaches you a harsh truth about the game—you're no bullet sponge, and a few well-placed shots or a single rocket will put you down. It forces you to be clever.

We're used to a single-player campaign being mere training for multiplayer, and there's certainly a bit of that going on here, but the War Stories ascend beyond that. Each is self-contained, and differentiated enough in their plots, characters, and settings to not feel familiar, even if they often fall back on the "approach objective and shoot everyone or blow it up" style of play. Objectives can often be tackled in any order, and this feeling of versatility and variability carries over to multiplayer.

Grand Operations is probably the best mode so far, although there are plenty of others if it doesn't catch your attention. It chains together different styles of play to create a campaign that takes place over a couple of days, throwing you into large-scale battles as well as tighter maps.

Visually, it's highly accomplished, but there are glitches. It freezes for a few seconds every so often on our AMD/Nvidia setup, with the CPU nowhere near maxed out. Then there's the pop-in, with rocks and piles of snow teleporting into place as you approach them. In War Stories, enemy soldiers can be dumb enough, depending on difficulty setting, not to notice their friend being shot in the head, as long as you suppress the gunshot.

Owners of RTX hardware will see performance increases as patches drop to improve ray tracing, but for the majority without it, this is still a good-looking, fast-paced action game, with top-rank multiplayer and single-player stories that can be genuinely affecting. **–IAN EVENDEN**

VERDICT 8

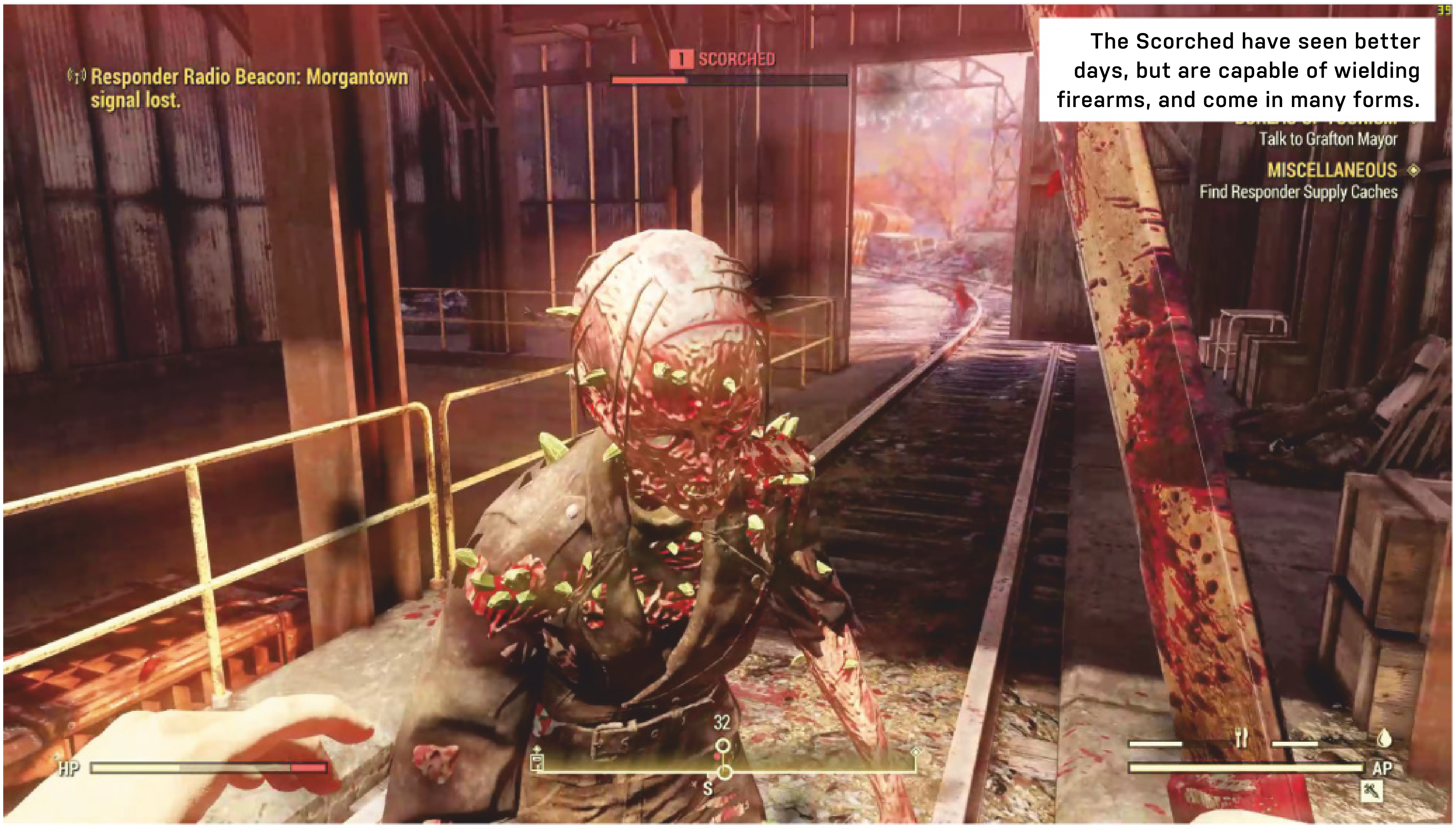
Battlefield V

+ MARINES Looks good; some excellent single-player writing; more multiplayer than you'll ever need.

− LATRINES Occasional glitches and graphical artifacts; not a good buy if you're not into multiplayer.

RECOMMENDED SPECS i7-4790/Ryzen 3 1300X; 12GB RAM; GTX 1060/RX 580.

$60, www.battlefield.com, ESRB: M


Responder Radio Beacon: Morgantown signal lost.
1 SCORCHED
Talk to Grafton Mayor
MISCELLANEOUS
Find Responder Supply Caches
32
S
HP
AP

The Scorched have seen better days, but are capable of wielding firearms, and come in many forms.

Fallout 76

Rebuilding civilization is a lonely task

MULTIPLAYER FALLOUT sounds like a good idea. Teams of survivors emerging from their vaults and working together to rebuild a civilization in a retro-futuristic, post-apocalyptic world, where energy weapons and robots exist, but cars have fins, and computers look like the IBM model 5150's grandaddy. There would be monsters or raiders to fight, radiation to avoid, and missions to complete for NPCs. It's easy to see how it could work.

The reality is different. You do indeed emerge from a vault, years after a nuclear war, as is *Fallout* tradition, but everyone else is long gone. Perhaps you overslept, but whatever kept you from leaving Vault 76 at the same time as the others, it did you a disservice. You're left alone in the empty wilderness, following the messages left for you by the vault's overseer. And no, you don't need to have played *Fallouts 5* to *75* to understand what's going on.

Before we get on to the wilderness, however, we must address the launcher. Instead of releasing the game on Steam, Bethesda has created its own marketplace. It's not bad—although it lacks community features and the ability to take screenshots with a hotkey—and if you want to get Bethesda games such as *Wolfenstein* or *Dishonored 2,* it's the place to go. It's also blurry on 4K monitors, and doesn't like it if you've got a multi-screen setup and move it from one to the other. The "Buy Now" buttons on games don't give a price, but open a browser window for an online store. It doesn't remember your password, and logs you out after a few days. There's a long way to go.

Back to the game, and the wasteland is living up to its name. The feeling of emptiness, despite running into some suitably mutated wildlife, is exacerbated when you reach the first town and find only robots. There are no human NPCs, just robots, computer terminals, and audio logs. There are other players—it's an always-online multiplayer game—but they're sparse, and often separated from you by several levels. You'll be reading this much later, but we were playing in the first weeks after launch, and saw almost no one of a similar level as ourselves.

Being an RPG, level is everything. You level up through doing things, killing things (crystalline mutants called the Scorched are the main antagonists), and crafting things, and you receive perk cards you can apply to all your attributes that boost skills, such as how much you can carry, how long you can go without food and water, and how well the VATS targeting system works. VATS, a mainstay of previous *Fallout* games, that stops time and allows pinpoint attacks, as well as explosive gore-shots of bullet strikes, has been gutted. The time-stopping was never going to work in a multiplayer game, but the kill-cam shots have gone, too, leaving just a real-time limb-targeting system. It's barely worth it.

If you can get in a group with other players of a similar level, there's some good questing to be had, and the autumnal West Virginia wilderness is an attractive place to spend time, despite the LOD pop. Over this, however, towers the loneliness, and so much glitchy bugginess (patches have been incoming) that this is currently looking like an experiment that's seen limited success. **–IAN EVENDEN**

VERDICT **6**

Fallout 76

⊞ **NUCLEAR** Lush forests and detailed ruined towns; good perks system.

⊟ **LONELIER** Bugs, and not just the radioactive ones; lack of other players.

RECOMMENDED SPECS i7-4790/Ryzen 5 1500X; 8GB RAM; GTX 970/R9 290X.

$60, http://fallout.bethesda.net, ESRB: M

LAB NOTES

ZAK STOREY, DEPUTY EDITOR

A Privilege and an Honor

It's been a fun ride, but it's time for me to move on

WELL, FOLKS, this is my 46th and final issue of *Maximum PC*. My time as deputy editor has come to an end. One of our publishing house's latest acquisitions, Tom's Hardware, has sounded the call for a new associate editor, requesting I take up that mantle for a new project it's developing. Unfortunately, that means I have to say goodbye to a team, a magazine, and a community that I absolutely love.

I owe a lot to this little ol' magazine of ours. It's taught me so, so much over the years. From honing my writing style to pushing me to the absolute edge of my limits, both technologically and creatively, It's been an absolute honor to have been a part of *Maximum PC's* journey over the last three years, and one I won't forget.

Working here has introduced me to some exceptionally talented people. From my remarkably supportive and knowledgeable editor, Alan, to our diligent, hard-working, eclectic art editor, Fraser, to the literary sub-editor genius that is Katharine, perpetually working hard to ensure my words make sense, and, of course, all the countless freelancers, staffers, and writers who pour their heart and soul into making this magazine what it is. They are all phenomenal, and I wouldn't be where I am today without their help and support.

Most importantly, I want to thank you. Thank you for subscribing, for buying *Maximum PC*—it means a lot that you have faith in us to produce the content we do, even with my occasional blasphemous hiccup, and it's a credit to *Maximum PC* that you're so passionate about this mag. Thank you, everyone. I'll miss this place.

JARRED WALTON

Senior Editor

I've heard credible rumors that suggest by the time you read this, Nvidia will have announced its RTX 2060 graphics card. I'm not sure what to make of that, since the RTX 2070 already struggles with real-time ray tracing. How will an even slower part manage? Probably not too well. The saving grace is that the RTX 2060 may be close to GTX 1070 Ti levels of performance, with an official MSRP of just $350. Which means another sidestep relative to the 1070 in existing games, with future potential when games start using DLSS and ray tracing. If all goes well, we'll have the full review next month—along with a Titan RTX, for those with very deep pockets.

BO MOORE

Hardware Lead

This issue went to print just before I left for CES, so I'll use this space to talk about my hopes for the show. 2018 was a good year for gaming laptops, but I think 2019 will be even better. The small, thin, and light formula of Max-Q machines has been successful, but we haven't seen an update to the graphics hardware since the 10-series Max-Q cards launched in 2017. I expect that to change, and will be surprised if we don't see RTX 20-series cards in gaming notebooks soon. The power increase will be nice for sure—the big question is price. The desktop RTX cards are expensive, so how will their notebook variants be priced? We'll find out soon.

Editors' Picks:
Digital Discoveries

Executive editor, Alan Dexter, and hardware staff writer, Joanna Nelius, reveal what's been entertaining them

SUBNAUTICA

At the tail end of last year, Epic announced that it was introducing a new games store to compete with the likes of Steam, Origin, Uplay, and their ilk. Obviously buoyed by the success of *Fortnite,* the *Unreal* developer decided to sweeten the deal by giving away some games to get people interested. The first of these was *Subnautica,* a game I'd never spent any time with, despite it getting rave reviews pretty much everywhere.

If you were lucky enough to grab it while it was free (or you fancy treating yourself), I urge you to spend some time in its beautiful, terrifying waters. Somewhat akin to *Minecraft,* with its exploration, survival, and building mechanics, I was happy enough uncovering the depths of its wonderfully realized world, well before the story began to unfold and reveal a game that's far more compelling than it may originally appear.

We're all used to experiencing early-access survival games that lack real meat, but here is a fully realized game that will at turns surprise and scare the brown stuff out of you. Of course, it helps that it looks and sounds gorgeous, and there are moments when I've simply enjoyed the underwater delights that unfold.

$20, www.subnauticagame.com

LOGITECH G403 PRODIGY WIRED GAMING MOUSE

Finding a comfortable gaming mouse has been a bit of a struggle for me. Most mice are either too wide for my palm or the body is too long for my fingers. If I want to use the thumb buttons, I have to lift my palm up and grip the mouse in a claw-like manner to reach them. If the mouse body is too wide, my pinky locks up sometimes if I've been gaming for too long. All around not comfortable. But I think I might have finally found something that won't set me up for carpal tunnel—the Logitech G403 Prodigy.

I've been looking for a mouse to replace my Corsair Sabre for all the above reasons for a while. Going from the Sabre to the G403 has made my hand so much happier. My palm rests comfortably on top, and my thumb can easily reach the side buttons. The arched padding beneath makes it glide around my mouse pad more smoothly, and it's lighter than the Sabre by 13g. I'm not climbing out of bronze in *Overwatch* anytime soon, but movement feels more precise with the G403. The G403 also has a 12,000 dpi—2,000 more than the Sabre—and the same refresh rate. Sometimes, the smallest differences in a gaming mouse can be the biggest ones.

$70, www.logitechg.com

GEEK TESTED & APPROVED

Corsair Hydro H100i Pro

I BUILT MY POP A RIG out of old parts we had lying around the office a few months back. It's a pretty slick build: an Intel Core i7-5820K, 32GB of Crucial Ballistix memory, an EVGA X99 microATX mobo, a GTX 1080, and a few budget SSDs to keep him chugging along nicely. He doesn't do much on it nowadays—just the occasional game of *World of Warships,* and I hear his future stepson is obsessed with playing *Fortnite* on it (no surprises there, then). Unfortunately, the cooler recently decided it'd had enough of the whole pumping water around business, and decided to kick itself to death. So, here we are, in need of a new cooler.

This wouldn't be a problem if the old fella lived just down the road, but as he's a four-hour drive away from me, I need something easy to fit on the fly, with little fuss, that he can manage. The current cooler is based off Asetek's AIO design, so swapping it out for something similar shouldn't be too much of a hassle.

So, easy Christmas present from me, then, this year! I went and got him arguably the most recognizable and reliable AIO on the market: Corsair's Hydro H100i Pro. It's a bit pricey, but if you're after something solid, with good performance, and an impeccable warranty, you can't go wrong with it. It'll also add more RGB to his rig, which will entertain me no end, given he's a 51-year-old man with no time for that nonsense. Or so he tells me. **–ZS**

$110, www.corsair.com

LETTERS

WE TACKLE TOUGH READER QUESTIONS ON...

> Aural Perfection
> Spelling It Out
> Sound Advice

Music to Your Ears

I'm a musician, and do a lot of original music recording and editing on my computer, so the sound produced by my PC is very important. I currently use various USB music hardware interfaces (Presonus Audiobox II or a Roland GR 55 guitar/bass synthesizer) to generate sound to both my Sennheiser headphones and a pair of JBL 305P MkIi 5-inch studio monitors, and although the quality is very good, I was wondering if bypassing these interfaces and instead using a kick-ass soundcard would make it even better. I initially mix songs with the Sennheiser headphones on, but also mix with the JBL speakers. The quality of the mix can change between headphones and studio monitor speakers, and the final mix is done on the JBL studio monitor speakers. If a great soundcard is better for this, it's time to order one. What, if any, soundcard do you recommend? The card must have stereo output jacks for a pair of 1/4-inch RCA plugs for the JBLs and a separate 1/8 or 1/4-inch jack for the headphones. The speakers are externally powered, so the output jacks need not provide that, obviously.

–Rick Breckwoldt

ZAK STOREY, DEPUTY EDITOR, RESPONDS: Soundcards are few and far between these days, and with good reason. Over the last five to ten years, we've seen motherboard manufacturers invest more and more money into their audio componentry, to such a degree that soundcards no longer seem to serve much of a purpose. I remember chatting with an Asus PR nearly three years ago, and he told me that the audio components on the (at the time) new Z170 boards had a value of nearly $100, even before factoring in the PCB separation. This put it in the same ballpark as most high-quality soundcards. Combine that with the limited space available, and the need for ever more inventive EMI shielding, and the logic just wasn't there to invest in soundcards anymore.

External hardware removes the EMI factor, and gives manufacturers an isolated environment to develop their hardware, without having to worry about what you have in your rig. Couple that with an entirely digital connection standard via USB, which introduces zero electrical noise, and development for soundcards fizzled out.

That said, Schiit (www.schiit.com) is our go-to brand for DACs and pre-amps. I've had a lot of fun with the Magni and Modi combo, a headphone pre-amp and DAC, but you might want something with a bit more grunt.

Spraying Mistakes

I've been reading your mag since it was *boot* magazine. I've enjoyed all the high-end tech you've shown, even when I couldn't afford it. I've learned a lot from your building PC articles and software tips and techniques. I read the "Tech Triumphs and Tragedies" article in the December 2018 issue. I was very interested in the MXeme antenna. It was developed by my alma mater, Drexel University. Unfortunately, the name was spelled "Drexil" in the article. Everyone makes mistakes, but I'm disappointed that this was not caught before publication.

–Stephen Fernald

ALAN DEXTER, EXECUTIVE EDITOR, RESPONDS: The stories in "Tech Triumphs and Tragedies" are always very tight for space, and there's plenty of editing and tweaking to try to get the information across in the most terse way possible, which can lead to errors like this, where someone like my good self edits the story after the usual subs, and introduces something glaringly stupid. You know, such as spelling the university so badly that we have a wealth of letters pointing out our stupidity (yours was the most printable). Which may have been what happened here. Apologies.

I'll try to distract you by providing a link to the technology involved, which is very cool. Check it out at: https://drexel.edu/now/archive/2018/September/MXene-spray-antennas/

Budget Hero

Was that Satan I saw buying a parka at the coat factory? It's been more than three

↘ submit your questions to: comments@maximumpc.com years since *Maximum PC* used or reviewed a case with 5.25-inch drive bays. With the $285 build, you used a case that not only had 5.25-inch bays, but also a 3.5-inch floppy bay. No, I will not let the word "retro" be used here. Did you know that 5.25-inch drive bays can be used for more than optical drives? You can buy USB 3.0 hubs with up to 10 ports that fit in 5.25-inch bays. You can use the bays for fan controllers and/or temperature monitors. There are plenty of other things that can be done with a 5.25-inch drive bay; you just need the imagination.

If you'd shopped around, you could have saved $20 on the case. You should have also gone with the cheaper mobo. Then you could have got an 8GB memory stick instead of 4GB. I'm surprised you don't know that when using integrated graphics, it uses system memory for graphics processing. You didn't mention how much memory you dedicated to graphics—most systems only let you max out at 1GB; using less is only good for word processing and email. If you did that, you have just 3GB for the OS and apps.

Three items that seem to not be included in all builds except the Dream Machine are a mouse, keyboard and monitor. I don't know anyone who would spend $450 on a mouse, other than you people. A decent keyboard and mouse combo can be had for around $40. A 14-inch brand-name monitor is less than $80. A no-name monitor can be had for about half that.

And lastly, Windows Home. Windows Home? Let's build a decent system and neuter it with Windows Home. **–Fake Account**

ALAN DEXTER, EXECUTIVE EDITOR, RESPONDS: You can always find better deals when building to a super-tight budget. There are bundle deals to look out for, sales, second-hand machines, and refurbed parts. The problem as far as the magazine is concerned is that such parts can be one-offs, or particularly hard to find, which means our readers' experiences can differ significantly. Throw in personal preference, and there's room for a lot of variance when it comes to a budget system. The point of our builds is often to spark the imagination, with a rough blueprint of one direction you can go. The rest is up to you.

Your recommendations for memory are a case in point, although we'd recommend a pair of 4GB sticks, as opposed to one 8GB, to improve memory throughput, but I'm sure you know that, and are just testing us. Obviously integrated graphics use system memory; what else would they use? For that system, we'd recommend setting the iGPU memory to much lower than 1GB, as it's not really a gaming machine, so 256MB would be sufficient.

Peripherals are such a personal preference that we don't tend to cover them in our general builds—we've spent $20 on budget options before. I'm pretty sure we've never seen a mouse that costs $450. As for screens, I'm confused about your preference for 14-inch panels. A 22-inch screen can be had for that much cash. It's not always the case, but bigger is definitely better here.

Finally, there's the Windows Home debate. Neutered seems a bit strong. Which parts of Pro do you need for your budget machine: Domain Join Services, BitLocker, Remote Access, Group Policy Editor, or Windows Update for Business? None of those seems essential for a budget machine.

[NOW ONLINE]

HITMAN 2: WHAT YOU NEED FOR 60FPS

Hitman 2 is essentially more of its predecessor, which is no bad thing. However, it does look a bit more impressive, with denser crowds, and some extra bells and whistles. But how well does it run compared to 2016's *Hitman?*

A major talking point is that DX12 was dropped for the new game, which is odd, considering it was in the previous one. It's even more confusing considering *Hitman* was one of the best DX12 implementations. It speaks to the amount of work required to maintain two APIs, and with a lack of AMD branding this time, apparently DX12 was deemed unnecessary. Read the full article at https://bit.ly/2VqfoHL

Clone Ranger

I've been a fan of *Maximum PC* for a long time. Thank you for the excellent article on cloning and partition backup. The importance of using a backup/image plan can't be stressed enough—your article was spot on. I had a mini disaster just this morning, but because I always image for backup purposes, I was back up and running in 10 minutes. I do have to give a huge nod to AOMEI Backupper. It has been my favorite for a few years. When I switched from an AMD motherboard to an Intel one, I thought I would have to reinstall Windows and everything that went with it. Then a friend introduced me to Backupper. It took the image I made from the AMD mobo and cloned it to new one without a hiccup. Awesome! There is a free version, too. **–Mike**

ALAN DEXTER, EXECUTIVE EDITOR, RESPONDS: The frustration with backing up is that most of us don't do it until we've lost something important. Glad you were covered, and thanks for the recommendation.

More Sound

Love the magazine and the builds at the back. I'm looking at ordering a new PC, and one option I never see in your builds is a soundcard. Do you feel they are no longer worth the money? Is there no reason to buy one anymore? I can't recall seeing one reviewed in your pages for a long time. **–Chris Ramirez**

ALAN DEXTER, EXECUTIVE EDITOR, RESPONDS: Check out this month's first letter, from Rick, on a similar line. To sum up, the audio solutions found as standard on modern motherboards are now so good that you don't need an add-in card. And we haven't looked at a soundcard for a while, because they're rare beasts these days—we keep an eye out, but the market has pretty much died.

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THE BUILDS

BUDGET

MID-RANGE

INGREDIENTS

PART		PRICE
Case	BitFenix Nova TG	$55
PSU	450W EVGA 450 BT 80+ Bronze	$30
Mobo	ASRock AB320M-DGS	$50
CPU	AMD Ryzen 5 2600 **NEW**	$165
GPU	Gigabyte GeForce GTX 1060 3GB **NEW**	$200
RAM	8GB (2x 4GB) Patriot Viper 4 @ 3,000MT/s **NEW**	$60
SSD	120GB SanDisk SSD Plus	$24
HDD	1TB Hitachi GST Ultrastar A7K1000	$35
OS	Ubuntu Desktop Linux 18.04 LTS 64-bit	$16
Approximate Price:		**$635**

WE'VE TAKEN A SIGNIFICANT HIT on the budget build this issue, but not without gain. We've managed to switch out that aged GTX 1050 Ti for our favorite GPU of the last two years, the GTX 1060 3GB. It's a budget 1080p killing machine. Yeah, perhaps the 3GB of VRAM isn't as future-proof as we'd like, especially in the bigger AAA memory-hogging titles, but it's difficult to argue with how much better value this thing is over its 1050 Ti sibling. For $20 more, you get 50 percent more CUDA cores than the Ti, plus significantly higher boost clocks and memory clocks. We've also plumped out some more cash to upgrade the Ryzen 3 1200 to the Ryzen 5 2600, a six-core 3.9GHz processor. This effectively gives us an additional eight threads to play with, and an impressive 0.5GHz increase to the boost clock, along with all the memory latency enhancements Zen+ offers up.

INGREDIENTS

PART		PRICE
Case	Fractal Design Meshify C	$90
PSU	550W EVGA SuperNOVA 550 G2 80+ Gold **NEW**	$70
Mobo	Asus ROG Strix B450-F Gaming	$125
CPU	AMD Ryzen 7 2700	$270
Cooler	Corsair Hydro H100i Pro 240mm RGB AIO	$110
GPU	Asus GeForce GTX 1070 Dual **NEW**	$335
RAM	16GB (2x 8GB) G.Skill Aegis @ 3,000MT/s	$103
SSD	250GB Samsung 970 Evo M.2 PCIe SSD	$78
HDD	1TB Hitachi GST Ultrastar A7K1000	$35
OS	Windows 10 Home 64-bit OEM	$100
Approximate Price:		**$1,316**

NOT MUCH CHANGE to our mid-range build. We've been able to keep the price to $1,300 bucks or so, but the great savings we managed to secure last issue on our GTX 1070 Ti are no longer available, and it has bounced back up to $450 as a minimum. That's a shame, as those GPUs essentially act as a slightly nerfed GTX 1080, but for about $100 less usually. We'll keep an eye on that, as we expect it might be foreshadowing a GPU release. Yup, we're talking the RTX 2060, or whatever it'll be called. If it's not as powerful as a GTX 1070 Ti, we'll be highly surprised. Hopefully, it will be priced accordingly, and we can slot it straight into our mid-range GPU slot. In a few months (with the advent of multiple QLC drives), it might be time to swap out that hard drive, too, for something a bit more flashy. Rumor has it Samsung is about to drop some seriously cheap 1TB $150 drives, so we're holding out on that, too.

TURBO

WOW, WE'VE SAVED $200, and are under $3K. This turns into a bit of a contest for us each issue, trying to spec the right parts, with the right performance, at the right price. We've made some substantial changes this time. The motherboard's been switched to ASRock's X399 Phantom Gaming 6, thanks to an impressive $50 saving compared to last issue. We've also decided to err on the side of caution for cooling, and have gone for a full-sized Noctua air tower. The NH-U14S is specifically designed for Threadripper, packing a full-sized CPU block, and enough grunt to tackle even the most heady of overclocks on our 2950X, no sweat. She's a beast, and if you can get past the beige and brown, there's something quite attractive about it, especially if you can get the fans spinning at a low RPM.

Other than that, we've just played around with the models more than anything else. We've gone with EVGA's RTX 2080 Black Edition, to save us $50, and have been lucky enough to receive some heavy discounts across many of the remaining products.

What we will say about this build is that it's really flexible, depending on how many cores you need. The 2950X is a fine processor, and with 16 cores, it'll manage whatever you throw at it. If you game more, though, we recommend the 2920X instead; and if you need something more "enterprise," throw the memory out for some ECC stuff, and chuck in a 24-core or 36-core WX part instead.

For more of our component recommendations, visit www.maximumpc.com/best-of-the-best

UPGRADE OF THE MONTH

SAMSUNG
Solid State Drive

1TB SAMSUNG 860 EVO

Nothing says enjoyment quite like instantaneous load times, especially in game. Samsung's 860 Evo is exceptionally good value for money now. You can currently get the 1TB variant for a little under $148, which is just awesome. A year or two back, this thing would have set you back near enough $350. The margin between hard drives and flash seems to be shrinking, something we thought would never happen, but given the way things are developing, old-school hard drives may very well be on the way out.

There are a few other options out there for solid-state storage at this capacity and this price point, but with a five-year warranty and some impressive performance, there's very little reason not to go with Samsung right now.

$148, www.samsung.com

INGREDIENTS

PART		PRICE
Case	NZXT H700i	$180
PSU	Corsair RM750x White 750W Gold Certified	$100
Mobo	ASRock X399 Phantom Gaming 6 **NEW**	$250
CPU	AMD Threadripper 2950X	$900
Cooler	Noctua NH-U14S TR4-SP3 Air Tower **NEW**	$80
GPU	EVGA GeForce RTX 2080 Black Edition **NEW**	$700
RAM	32GB (4x 8GB) Corsair Vengeance LED DDR4 @ 3,000MT/s	$270
SSD	512GB Samsung 970 Pro M.2 NVMe	$168
HDD	2x 2TB Seagate BarraCuda ST2000DM006	$120
OS	Windows 10 Home 64-bit OEM	$100

Approximate Price: $2,868

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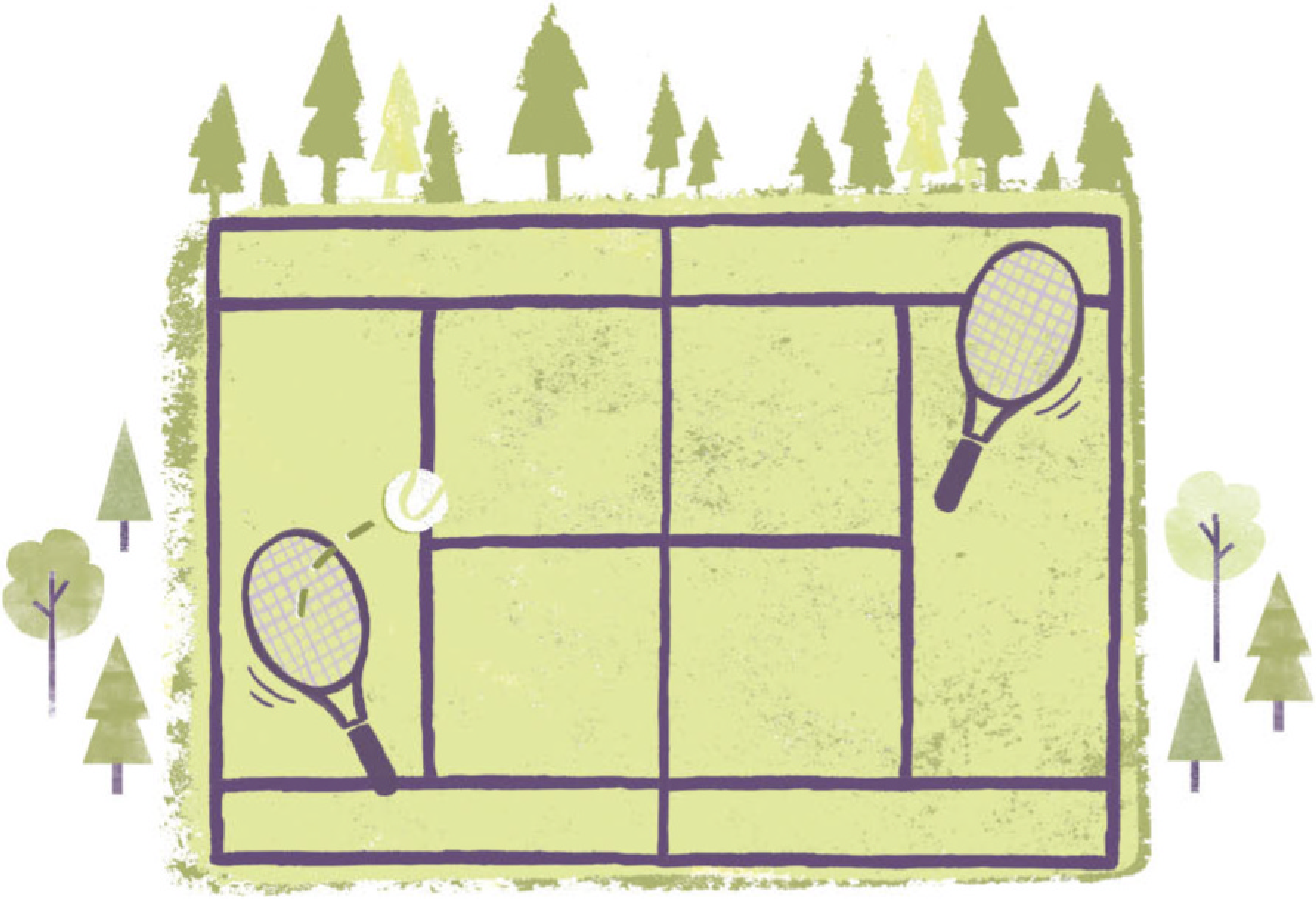

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UNFAO, Global Forest Resources Assessment 2005-2015

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